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YELLOWS AND NECROTIC RING SPOT OF SOUR CHERRIES IN ONTARIO: INOCULATION EXPERIMENTS[1]

G. H. Berkeley and R. S. Willison

(Accepted for publication, February 10, 1948)

In 1939 Keitt and Clayton (4) reported that the disease of sour cherries, previously known in Wisconsin as physiological yellow leaf, was graft-transmissible and therefore of virus origin. They proposed renaming the disease cherry yellows (5). Two years later, 1941, experimental evidence was obtained in Ontario, that the so-called physiological yellow leaf long prevalent in that Province was also caused by a virus and could be transmitted to Montmorency cherry and to peach by budding. Comparison of symptoms on sour cherry left little doubt that the Ontario disease was cherry yellows.

A second disorder of sour cherries, now called necrotic ring spot (1), has also been present in Ontario for many years, though not recognized until 1939. In 1940 this disease was shown to be a virosis when typical symptoms were expressed on Montmorency and a variety of Duke cherry as a result of inoculation by budding from affected trees.

Both these diseases have been found widespread in sour cherry orchards in Ontario and are often responsible for considerable reduction in yield. The present paper is a report on certain phases of the investigations of these two diseases, carried out over the last seven years.

SYMPTOMS ON MONTMORENCY

Cherry yellows. In Ontario, diagnostic foliar symptoms usually appear, about three or four weeks after petal fall, as a mottling of the leaves with chlorosis between the veins or as a more or less complete yellowing, depending on the severity of symptom expression. In general, the tissue along the larger veins retains its green color after the interveinal portions have turned yellow (Fig. 1, A). Soon after the color change, the affected leaves drop, though in some seasons it is not uncommon for green leaves also to be cast. In some cases comparatively slight casting of leaves occurs, while in others the defoliation is so severe that the ground is literally covered with leaves. Environmental factors, especially the temperatures prevailing during leaf development, as shown by Moore and Keitt (7) and Mills (6), play an important role in determining the amount of defoliation.

There is generally but one wave of defoliation of any consequence in Ontario, usually in mid-June. Some yellowing and casting of leaves may occur later in the season but this is not common and is very limited in amount and duration. Diagnosis of cherry yellows in an orchard is therefore restricted to a period of from one to two weeks after symptoms first appear.

[1] Contribution No. 923 from the Division of Botany and Plant Pathology, Science Service, Department of Agriculture, Ottawa, Canada.

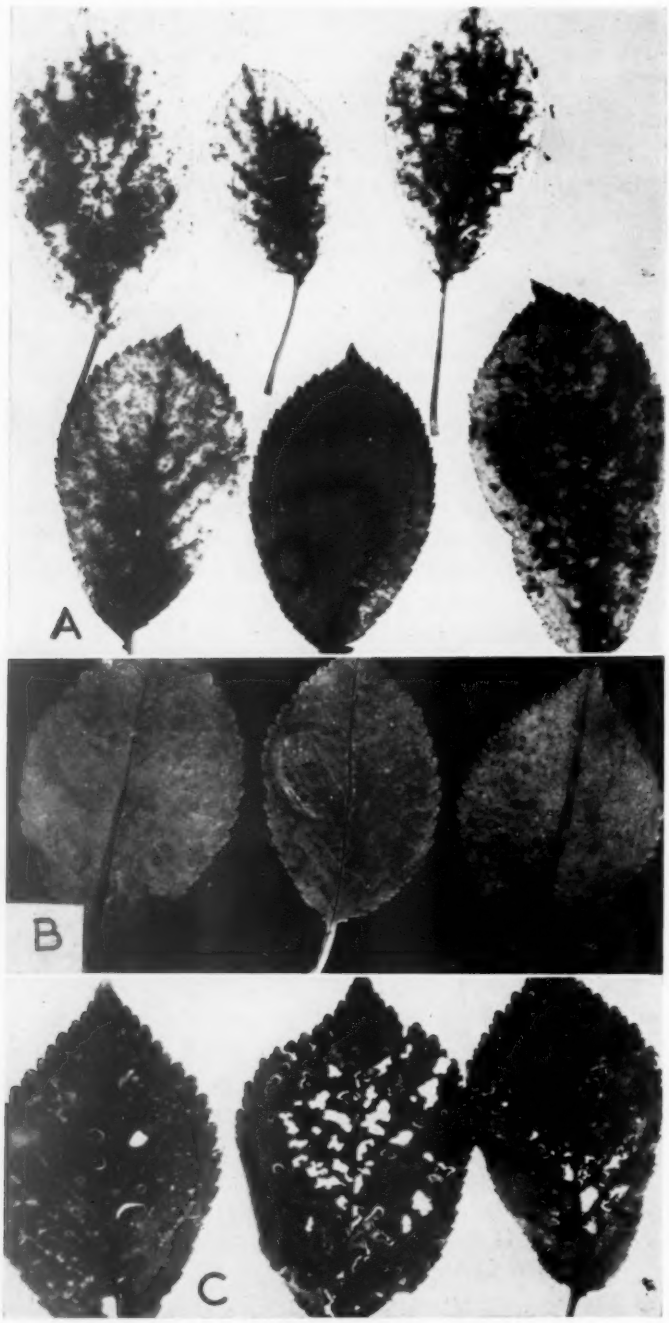

FIG. 1. A. Symptoms of cherry yellows on Montmorency, showing retention of green color around veins. B and C. Symptoms of necrotic ring spot on Montmorency showing ring spot (B) and shot hole (C) stages.

In addition to causing leaf symptoms, yellows also affects fruiting habit and growth. The spur systems of affected trees in time become greatly reduced, and with them the crop, though the fruit itself is of good quality and often larger than that on healthy trees. There is also a tendency for lateral leaf buds either to grow into shoots or, more often, to fail to develop. The ultimate effect is heavy leaf growth towards the tips of the branches and excessive lengths of barren wood back of the tips. Growth of this type causes the branches to droop, giving a "weeping" effect. This characteristic alone is not regarded as a reliable criterion of yellows infection as it also may result from bud weakening or failure from other causes.

Yellows is not a lethal disease. Trees known to have been infected with yellows for several years still produce reasonably satisfactory crops.

Necrotic ring spot. The first and most striking symptom of necrotic ring spot is delayed foliation, which may be confined to a few branches only or may be more or less general throughout the tree. That is, at the time the first leaves on healthy trees are fully expanded, those on affected trees or branches may be partially unfolded or only just emerging from the bud (Fig. 2, B). If the first unfolding leaves on affected branches are examined carefully, numerous fine translucent to brownish spots, arcs, or rings having an etched appearance are evident (Fig. 1, B). Sometimes concentric rings are present. The surface of such leaves is rough and their margins are wavy, giving the leaves a crinkled appearance. In the earliest stages, the markings are seen best in reflected light. Later, chlorotic and necrotic areas develop, the necrotic tissue falls out, leaving the leaves "shot holed" or tattered, depending on the location and amount of necrotic tissue (Fig. 1, C). Often the tip, margin, and much of the lamina become wholly or partially necrotic. The remaining tissue is normal in color, though the leaves themselves tend to be considerably smaller and rounder than normal. Severely affected leaves are frequently cast but may persist throughout the season. The etched markings, if they do not become necrotic, tend to disappear.

Symptoms similar to those on the leaves also appear on the sepals. The blossoms may be almost sessile or have more or less shortened pedicels.

It is characteristic of necrotic ring spot that diagnostic symptoms are apparent only at the beginning of the growing season. A tree severely affected in May or early June may appear to be healthy later in the same season, and, moreover, has few or no symptoms in the second and succeeding years. However, if infection was localized in a few branches the first year, other branches of the same tree may be severely affected the next spring. In affected trees, with few exceptions, the severe or shock symptoms of necrotic ring spot are not recurrent, though mildly etched rings and markings are found frequently in any season on the first formed leaves. After the initial shock symptoms have developed, there is a tendency for the foliage to become less dense, so that the tree has a more open appearance than normal.

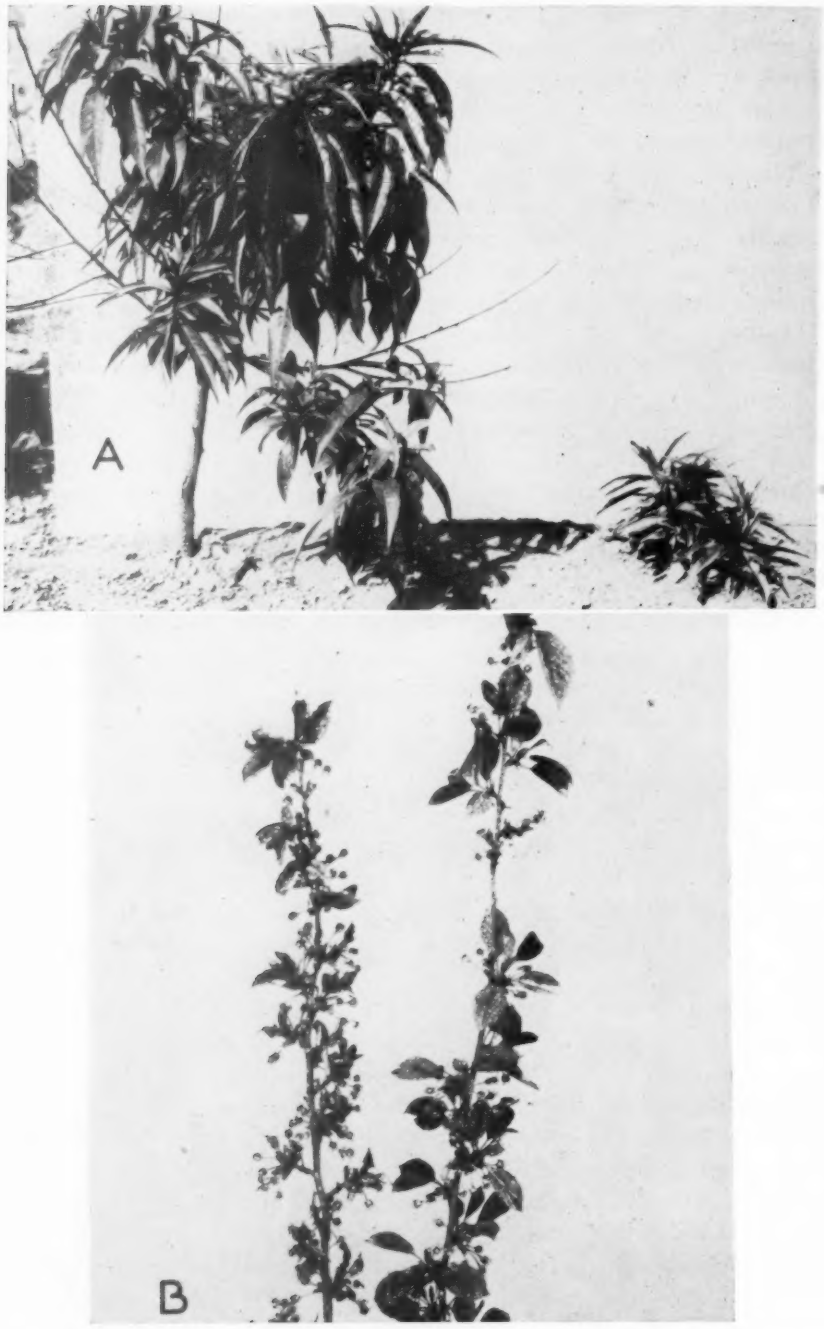

FIG. 2. A. Symptoms on peach inoculated with cherry yellows virus; left, die back and rosette on peach seedlings; right, rosette symptoms on peach which was cut back above inserted yellows bud. B. Delayed foliation from necrotic ring spot on Montmorency (left) in comparison with healthy branch (right).

TRANSMISSION EXPERIMENTS

Materials and Methods

To obtain sources of infective material, several orchards were surveyed twice annually, in early spring and in mid-June, to locate cases of necrotic ring spot and cherry yellows, respectively. At each survey, branches, from which bud sticks were to be taken later, were marked on selected trees showing symptoms of the required disease. For obvious reasons, the selections were divided into three categories: (i) trees in which only symptoms of necrotic ring spot were observed; (ii) trees showing symptoms of yellows but not of necrotic ring spot during the period of the surveys; and (iii) trees known to be infected with both diseases. In most cases, the orchards had been under observation for at least two years before bud sticks were cut. All inoculations were made outdoors by the budding method.

The range of differential hosts included *Prunus persica* (L.), var. Elberta and Rochester, and seedlings; *P. domestica* (L.), var. Italian prune and Lombard plum; and *P. cerasus* (L.) var. Montmorency. One- or two-

TABLE 1.—*Numbers of sources from which cherry yellows and necrotic ring spot viruses were transferred to the several hosts*

Host	Cherry yellows	Necrotic ring spot
Peach		
Rochester	8	4
Elberta	8	4
seedling	8	4
Italian prune	2	2
Lombard plum	4	4
Montmorency cherry	8	3

year-old nursery trees of the named varieties were used in most of the experiments. For the first trial, the nursery trees prior to inoculation were kept under observation for indications of previous infection. For subsequent experiments, selected variety clons were indexed to determine their freedom from virus infection, propagated on appropriate root stocks and inoculated as nursery stock, usually one year old. In one experiment, the double budding technique was employed with a healthy clon of Montmorency. That is, one or more buds from a diseased source were inserted in a *P. mahaleb* seedling, and above these a bud from the healthy clon. Inoculation of named varieties was carried out in duplicate. The peach seedlings were inoculated, in quintuplicate series, late in the first season of growth. Two seedlings in each series were cut back to the inserted diseased bud early the next spring, while the remaining three were left intact.

The numbers of different sources of each virus used on the various hosts are listed in table 1. In a number of instances, individual sources were used in successive experiments, but these duplications are not indicated in the table.

Results

In the several series of experiments, which were carried out over a period of four years, the results obtained with any one host were remarkably consistent. Consequently, to avoid unnecessary repetition, symptoms appearing on the different hosts can be described without reference to individual experiments. These are described in some detail below, and compared in table 2 with symptoms of prune dwarf.

TABLE 2.—*Comparison of symptoms of cherry yellows, necrotic ring spot, and prune dwarf observed on different hosts after inoculation by budding*

Symptoms	Peach varieties and seedlings[a]						Italian prune; Lombard plum			Montmorency cherry		
	A			B								
	NRS[b]	CY	PD	NRS	CY	PD	NRS	CY	PD	NRS	CY	PD
Shock symptoms												
Delayed foliation	0[c]	0	0	1–3	1–3	0–1	0	0	0	1	1	1
Die-back	0	0	0	1–3	1–3	0	0	0	0	0	0	0
Bark necrosis, splitting or roughening	0?	0?	0?	1–3	1–3	0–1	0	0	0	0	0	0
Chlorotic rings and mottle	0–1	0–1	0–1	1–2	1–2	0–1	0	0	0	0–1	0–1	0–1
Etched rings or markings	0	0	0	0	0	0	0	0	0	1–2	1–2	1
Necrotic spotting or flecking	0	0	0	S, F	S, F	0	F	F	0	S, F	S, F	S, F
Chronic symptoms												
Wavy margins	0	1	1	0	1	1	0	0	0	0	0	0
Strap-shaped, pebbled leaves	0	0	0	0	0	0	0	1	1	0	0	0
Shortened internodes	0	1–3	1–3	0	1–3	1–3	0	0	0	0	0	0
Yellowing and leaf casting	0	0	0	0	0	0	0	0	0	0	1–3	0
Recovery	R	r	r	R	Rr	r	R	R	0	R	R	R

[a] Varieties and seedlings in group A were cut back to the inserted bud; those in group B were not cut back.

[b] NRS denotes necrotic ring spot virus; CY, the cherry yellows virus; and PD the prune dwarf virus.

[c] 0 denotes no symptoms; 1, slight symptoms; 2, moderate symptoms; and 3, severe symptoms. F denotes flecking; S, spotting; R, recovery from shock symptoms; and r, partial recovery from chronic symptoms.

Symptoms on peach varieties and seedlings

Necrotic ring spot. On peaches inoculated with necrotic ring spot virus but not cut back to the bud, the first symptom to appear in the following spring was a pronounced delay in foliation, followed by varying degrees of die-back. In many cases, partial emergence of leaves occurred before the branch succumbed; in others, die-back took place before bud movement. Occasionally, two-year-old trees, as well as seedlings, were killed. The earlier formed leaves on the surviving branches frequently,

but not always, showed chlorotic spots or rings, often followed by necrosis. These markings tended to be confined to the basal portion of the lamina. A consistent symptom on one- or two-year-old trees and on the larger seedlings was bark necrosis resulting in a "rough bark" condition, or even in bark splitting, on trunks and scaffold branches. Surviving trees soon outgrew the non-permanent shock symptoms and appeared to develop normally later in the season except that growth was sometimes slightly less vigorous than in healthy trees of the same age. Shortening of internodes or rosetting of shoots was not observed. The shock symptoms did not recur in the second and subsequent seasons, though repeated tests demonstrated that infected trees continued to carry the virus after apparent recovery.

When seedling peach trees were cut back to the inserted diseased bud, they displayed no shock symptoms and proceeded to develop in a more or less normal manner. In other words, in such trees the disease passed directly into the chronic stage without going through the acute stage.

Cherry yellows. If they were not cut back, peach trees or seedlings inoculated with the virus by buds from Montmorency trees affected with yellows exhibited shock symptoms similar to, if not identical with, those induced by necrotic ring spot virus. This reaction occurred whether or not the virus of necrotic ring spot was known to be present in the source trees. On the other hand, instead of recovering, all the peach trees so far inoculated with yellows have produced shoots with shortened internodes. The virus from different sources, however, caused varying degrees of dwarfing, so that, with some, the internodes were only moderately shortened but, with others, were so reduced that the leaves were bunched together in loose rosettes. Variation in dwarfing arising from differences in the varietal reaction of the host have been of minor importance.

When peach seedlings were cut back after inoculation with yellows they also escaped the initial shock symptoms but showed the chronic dwarfing phase of the disease (Fig. 2, A).

Symptoms on plums

Necrotic ring spot. On both Italian prune and Lombard plum, the necrotic ring spot virus from six different sources induced varying amounts of small necrotic spots or flecks on the unfolding leaves, in the spring after inoculation. In one case, however, this symptom appeared in September after budding in August. The necrosis was usually mild, but sometimes was severe enough to give a scorched appearance to the affected leaves. The trees soon outgrew this condition, so that the leaves formed later in the season were normal. There was no recurrence of symptoms in succeeding seasons.

Cherry yellows. The cherry yellows virus from six different sources when transferred either to Italian prune or to Lombard plum caused a similar necrotic spotting of the unfolding leaves at the beginning of the

first growing season after budding. As with trees inoculated with the necrotic ring spot virus, these also soon outgrew the shock symptoms, but, in the second season, branches above the bud insertion produced spindly, stunted shoots bearing roughened or pebbled strap-shaped leaves like those associated with prune dwarf, caused by *Prunus virus* 6. The "prune dwarf" symptoms have increased somewhat in quantity in succeeding years, though spread through the tree has been slow. At time of writing, trees inoculated four years before have only a few branches showing symptoms of this type. Similar results have been observed in Italian prune and Lombard plum inoculated with the milder strains of the prune dwarf virus.

Symptoms on sour cherry

Necrotic ring spot. To date, in these experiments, the necrotic ring spot virus is known, from subsequent expression of symptoms, to have been transmitted to Montmorency cherry from only three sources. In each case, the etched and chlorotic rings and spots, and the necrosis typical of this disease but milder than that observed in nature, were obtained the year following budding. Later the trees appeared to become normal except for a tendency to general thinness of foliage. No symptoms of cherry yellows have been observed on these trees.

Cherry yellows. Cherry yellows virus from eight different sources induced in Montmorency cherries symptoms similar to those associated with the necrotic ring spot virosis. Either later in the same season or not until the second season after budding, typical symptoms of yellows developed. The amount of yellow leaf and defoliation varied considerably from tree to tree.

DISCUSSION

The differential reaction of peaches and Italian prune and Lombard plum to infection with the necrotic ring spot and cherry yellows viruses indicates that these hosts are of considerable value in the diagnosis of these diseases.

It is interesting to note that the symptoms resulting from inoculation with the necrotic ring spot virus are of the same general type, namely necrosis, whether peach, Italian prune, Lombard plum, or Montmorency cherry be used as hosts. Moreover, the sequence of symptoms is similar, namely shock or acute symptoms followed by recovery. That is, chronic symptoms are lacking except for the mild, inconspicuous ones which sometimes recur in Montmorency.

On the other hand, cherry yellows on the same hosts has not only an acute phase, as expressed by shock symptoms resembling those of necrotic ring spot, but also a chronic phase, characterized on Montmorency by yellow leaf and leaf casting; on Italian prune and Lombard plum by

symptoms of the prune dwarf type; and on peach by shortened internodes or rosetting.

In considering the problem raised by the fact that, in its acute phase, cherry yellows on three hosts is indistinguishable from necrotic ring spot, it should be borne in mind that the latter disease is caused by a virus entity distinct from that causing the chronic symptoms of yellows. This conclusion is based on observation of symptom expression on naturally infected Montmorency trees in the orchard as well as on the differential reaction of peach, Lombard plum, and Italian prune to the two viruses. The constant association of the "necrotic ring spot" phase with yellows infection suggests, however, that cherry yellows, if not caused by a single virus, may be caused by a virus complex of which the necrotic ring spot virus is one component.

There remains to be discussed the possible relationship between the cherry yellows and prune dwarf viruses, since the cherry yellows virus from six sources produced symptoms on Italian prune, Lombard plum, and peaches that are indistinguishable from those associated with prune dwarf caused by *Prunus virus* 6 on these hosts (3). This similarity of symptoms would suggest some close affinity between the causal viruses (Table 2). That they are not identical is indicated by the inability of the prune dwarf virus to produce either yellows on Montmorency or typical shock symptoms on peach and plum (2, 8). Accordingly, there would appear to be at least three possible explanations for the similarity and differences in the symptom expression of cherry yellows and prune dwarf:

(1) that the two diseases, though having some symptoms in common, are caused by two distinct virus entities;

(2) that three viruses are involved: one, probably the necrotic ring spot virus, responsible for the acute symptoms; one, the yellows virus, responsible for yellows symptoms on Montmorency and the prune-dwarf-like reaction on peach and plum; and one, the prune dwarf virus responsible for prune dwarf itself;

(3) that cherry yellows is caused by a complex, the components of which are the prune dwarf and necrotic ring spot viruses.

At the present time, the third explanation appears to be the most tenable as it is not probable, though admittedly possible, that two unrelated viruses cause, on the same hosts, symptoms so striking and unusual as those of prune dwarf on Italian prune and Lombard plum. Also, it is not necessary to postulate the existence of a second virus with the apparent characteristics of the necrotic ring spot virus. The evidence now available is not yet sufficient to decide the point, but experiments designed to supply the deficiency are now in progress.

The effect on symptom expression of cutting peaches back to the inserted buds in the spring following budding, as indicated in another connection by Willison and Berkeley (9), is regarded as being due to the

fact that the virosis does not become systemic on peach until after growth starts in the spring. According to this theory, acute symptoms are expressed if infection of the embryonic tissue occurs after differentiation, but only chronic symptoms appear when the embryonic tissues become infected before differentiation. Thus cutting back would remove the upper, non-infected buds and force the growth of adventitious shoots from previously infected tissue in the proximity of the inserted bud. Consequently the shock symptoms of either yellows or necrotic ring spot would appear only on peach seedlings not cut back after inoculation, and seedlings that were cut back would appear to develop normally if inoculated with the virus of necrotic ring spot, or express only the chronic symptoms if inoculated with yellows virus.

SUMMARY

1. The symptoms of necrotic ring spot and of cherry yellows, two viroses common on sour cherry in Ontario, have been described.

2. Inoculation experiments have demonstrated that necrotic ring spot has a short acute phase of the same general type on sour cherry, peach, Italian prune, and Lombard plum and a chronic phase characterized by the absence of symptoms on peach and plum, and frequently on sour cherry, on which, however, mild symptoms occur occasionally.

3. The acute phase of cherry yellows is strikingly similar to that of necrotic ring spot. The chronic phase on sour cherry is characterized by yellowing and casting of leaves in early summer; and on peach and plum, by symptoms simulating those of prune dwarf.

4. The possible relationships between the causal viruses of necrotic ring spot, cherry yellows, and prune dwarf are pointed out.

DOMINION LABORATORY OF PLANT PATHOLOGY,
ST. CATHARINES, ONTARIO, CANADA.

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A ROOT ROT DISEASE-COMPLEX OF SMALL GRAINS IN VIRGINIA[1]

WILBERT A. JENKINS

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A disease of small grains, herein shown to be one of the root rot disease-complexes, has been responsible for rather severe losses in Virginia over the past 6 years. Highest losses have been observed during late fall and early spring in plantings of wheat, barley, and oats. These losses have formerly been rather consistently attributed to winter injury, drouth injury, or to some more or less obscure phase of foot rot and Helminthosporium blight. In several instances, hasty diagnoses have attributed the trouble to insect injury within the crown of affected plants.

Investigations on root rot disease-complexes of tobacco under way at this Laboratory since 1942 have definitely proved the meadow nematode group to be the basic factor in certain root troubles of tobacco and have contributed materially to a better understanding of similar troubles of small grains.[2]

SUSCEPTS

Though wheat, barley, and oats are the more important of the graminaceous crops cultivated in this area and have therefore received the most attention in this study, identical disease symptoms have also been observed on numerous wild and cultivated grasses in this area. Information is also at hand indicating that numerous crop plants other than Gramineae may be suscepts. Most prominent among these are tobacco and several legumes.

SYMPTOMATOLOGY

When viewed in the late fall and early spring, small grains affected with the root rot disease-complex under consideration appear unthrifty and pale in color when seen from a distance. More or less bare patches are evident throughout the field (Fig. 1, A, B). On closer approach, individual plants over fairly large areas are seen to be stunted or in varying stages of death. Plants typically affected fail to tiller. The older leaves on affected plants have varying color patterns ranging from pale green through bronzing to lemon yellow. Often many dead leaves are to be found about the crowns of such plants (Fig. 2, A, B). Moderately and severely affected plants are generally "heaved" from the soil during periods of freezing and thawing, but it is not unusual for such plants to be uprooted in advance of freezing weather in the fall or following such weather in early spring. Stand losses ranging from 70 to 90 per cent

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[2] Jenkins, Wilbert A. Root rot disease-complexes of tobacco with reference to the meadow nematode; a preliminary report. U. S. Dept. Agr., Pl. Dis. Reptr. **28**: 395–397. 1944.

have been sustained on certain legume-small grain-tobacco rotation plats at this Laboratory, though field losses in general are considerably less. We have no reliable information on the loss in yield.

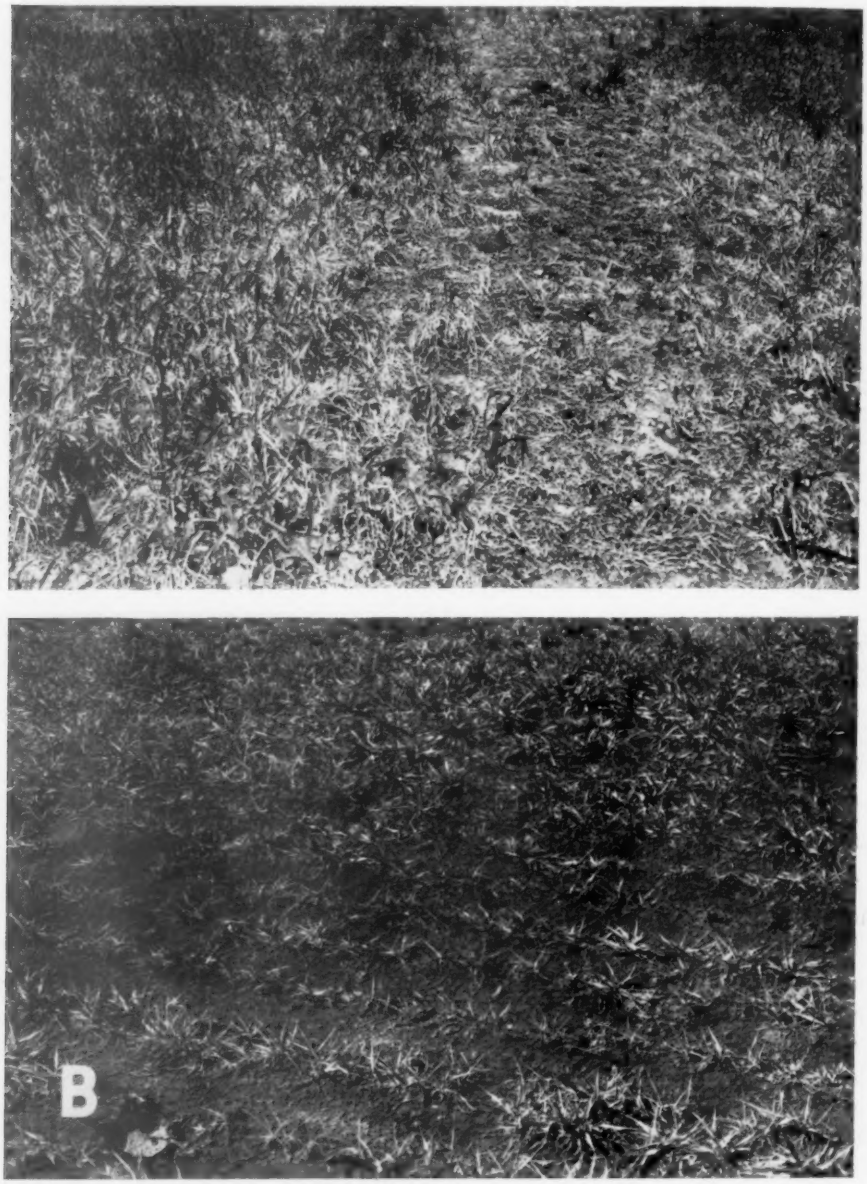

FIG. 1. Field views of small grain fields affected with root rot disease-complex. A. Patterns of destruction within a wheat field; B. Stunting and killing within a barley field.

When individual diseased plants are examined closely, a portion to all of the following symptoms are prominent on the above-ground parts. The

older leaves vary from pale green to lemon yellow, and some are completely dead. Some of the leaves are almost severed from the plants, the

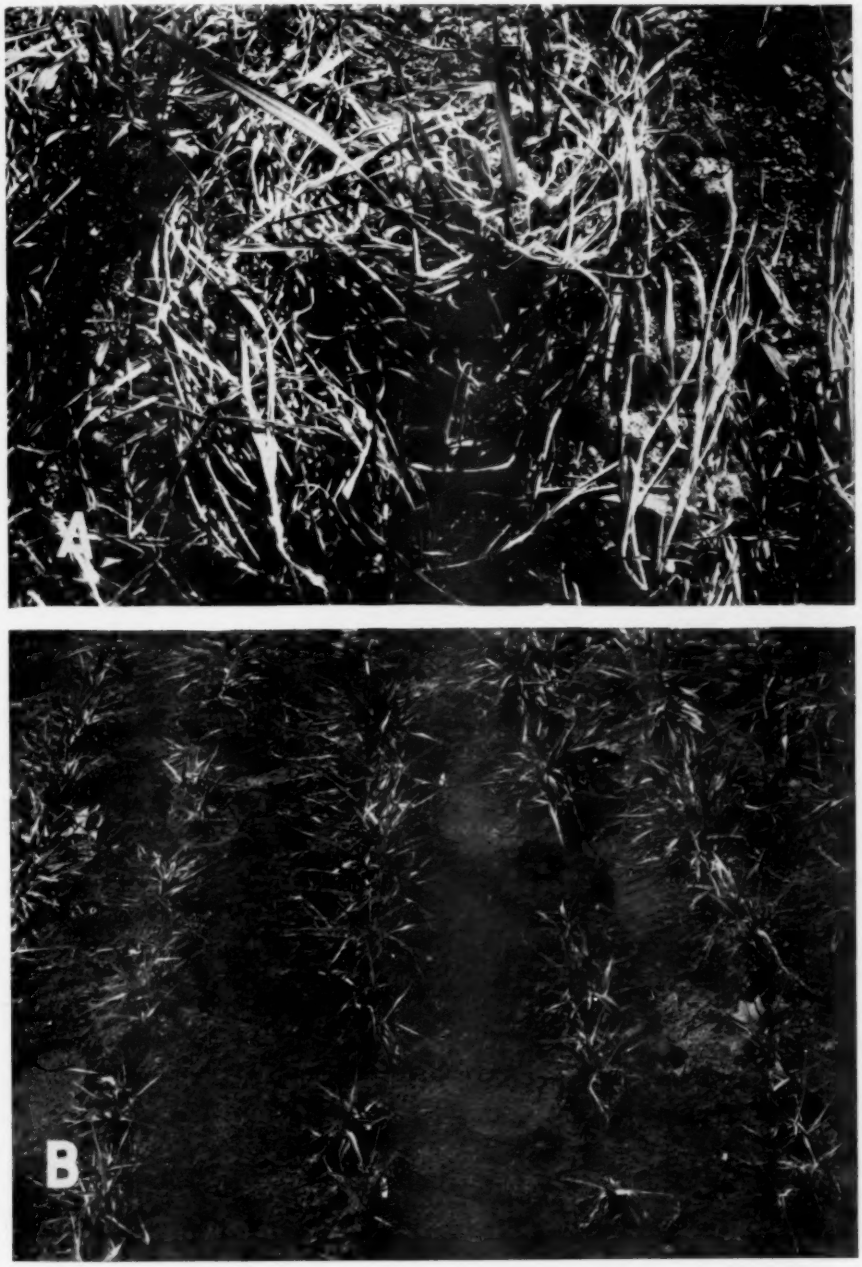

FIG. 2. Close-up view of diseased plants. A. Wheat; B. Barley.

impression being that they have been chewed off at or near the basal attachment. Such leaves readily fall from the plants when the supporting

soil is removed from about the base. The bases of such leaves present a frayed appearance due to the persistence of the larger vascular elements and quite often, particularly when the soil is moist, pronounced water-soaking occurs in and adjacent to the frayed portions. Severely injured plants often fail to produce seed heads. The inflorescence often fails to emerge from the boot and when it does, the grain is likely to be poorly developed.

Considerable root mutilation is evident in thoroughly washed root systems of affected plants examined under low magnification (Fig. 3, A). All stages between apparently healthy roots and badly mutilated roots can be found depending on the specimen at hand. The earliest indication of root disease is the presence of watersoaked lesions within the cortical tissues. These lesions rapidly change color, becoming pale yellow to tawny

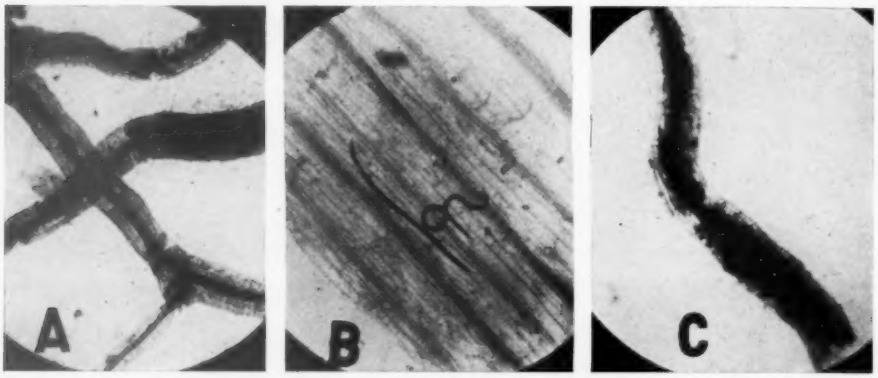

FIG. 3. Photomicrographic views of diseased portions of wheat. A. Extent of mutilation (girdling) of feeder roots; B. Parasitic nemas on and within the leaf tissues of crown; C. Parasitic nema adjacent to a girdle on a feeder root. Note the proximity of many girdles to young and old lateral roots. Roots fixed in Flemming's strong fixative. All photomicrographs × 72 (approximately).

colored as the disease progresses. In time the lesions assume a darker color, attended by a loosening of the cortex and slipping of segments of the cortical tissues in a collar-like or sleeve-like fashion. The underlying stele is various shades of yellow to almost brown in the areas where the cortex is loosened. It is not unusual to find many roots from which all cortical tissues have sloughed off leaving only the woody cylinder.

An examination of thoroughly washed plants, particularly in the crown area, reveals considerable mutilation of leaf bases and young buds. Nematodes may be seen embedded within the leaf tissues when the leaves are stripped from the plants and subjected to microscopic examination. A more accurate picture of infestation may be had by clearing the leaf tissue in warm lacto-phenol and staining lightly with acid fuchsin.

When the crown tissues are separated under suitable conditions and examined under a binocular (dissecting) microscope, many nematodes may be found outside the leaf tissues, but within the folds of the inter-

folded leaves (Fig. 3, B). Preparations for this examination may be made by (1) placing the crown in a preparation dish with a suitable amount of water and teasing the tissues apart under a dissecting microscope or (2) slicing through the crown with a sharp scalpel and then teasing the tissues apart. These preparations may be cleared in lacto-phenol and stained with warm acid fuchsin. Such preparations leave no doubt as to the feeding habits of the nematodes.

ETIOLOGY

Several different nematodes generally are associated with the symptoms described above, the dominant types varying in a large measure with the locality from which the specimens are taken and also with the portion of the plant under examination.

In the vicinity of Chatham and from several locations in the Winchester area of Virginia, the crowns and leaves of small grains are heavily infested with *Panagrolaimus subelongatus* (Cobb) Thorne and *Paraphelenchus pseudoparietinus* (Microletsky) Microletsky. According to Steiner, these two nematodes are usually associated with the type of disease under discussion and *P. pseudoparietinus* particularly appears to be a form with decided preferences for graminaceous hosts. In private correspondence under date of March 31, 1945, Steiner states, "We formerly thought this species an extremely rare one, but find it now everywhere we have opportunity to examine stems, leaves, and seed heads of cereals and grasses."

The roots of diseased small grains in the above mentioned areas are heavily infested with a *Ditylenchus sp.* (exact determination not made by Steiner) closely related to the stem and bulb nematode, and *Pratylenchus spp.*, among the latter being *P. pratensis* (de Man) Filipjev. In some fields *Ditylenchus* predominates, while in others *Pratylenchus* is dominant. These are the nemas which mutilate the feeder roots, thereby initiating a series of more or less complex physiologic and morphologic host reactions which culminate in the state herein designated root rot disease-complex (Fig. 3, C).

During the very early stages of infestation, when the roots show only inconspicuous, watersoaked lesions, no microorganisms can be isolated by bacteriologic techniques—or if cultures are obtained the inconsistency factor is too high to admit the presence of bacterial or fungus parasites. On the other hand, either of the following techniques always demonstrates the presence of nematodes within the lesions. To demonstrate living nemas in situ, the lesions may be teased apart within a limited quantity of water in a Petri or preparation dish under a dissecting microscope. Such roots should first be thoroughly washed in moderately cool water in order to cleanse the roots of any nemas which may be feeding or otherwise attached to the exterior surface of the roots. In order that the thoroughness of the cleansing may be checked, the roots which are to be dissected should be examined closely under a dissecting microscope, following the washing

process. If nemas are found in the water outside the roots, the cleansing process should be repeated until no traces of nemas are to be found outside the roots. With such a technique the degree of nema infestation cannot be determined but the method insures the observer against working with free living nemas which may also be in the environment. If the degree of infestation of roots is to be considered, and no reason is at hand for keeping the nemas alive, another much more rapid method of determination may be used. This method consists of the early stages of the technique just described, but instead of teasing the lesions apart, the roots containing them are placed in a small quantity of water (just enough water to cover the mass) in a 50-ml. beaker and heated to a temperature just below the boiling point of water. For practical purposes, this point may be assumed to have been reached when the water begins to send up air bubbles freely, but before the water actually boils. While cooling, the beaker should be placed on an uneven surface so that the nemas which have emerged from the lesions during the gradual rise in temperature of the water will be concentrated in a given area on the bottom of the beaker. From this area they can very easily be removed for examination by a small bore pipette and placed in a preparation dish for examination. Individual nemas may be removed with the aid of a pipette, bamboo splint, or a sharpened broom-straw, and placed on a slide for a permanent preparation. A very weak formalin solution makes an excellent mounting medium. Glass wool fibers should be placed within the medium in order to prevent crushing the specimen by the cover glass and each preparation should be sealed with wax in order to prevent it from drying out.

Other associates of root rot complex of small grains, including fungus and bacterial associations, are not specific. With care, any fungus or bacterial form known to be in the rhizosphere may be isolated from badly mutilated or decaying roots of diseased plants, depending on the moisture content and soil temperature relations during and just preceding the period of examination. As stated earlier, these bacterial and fungus associates are secondary and under our conditions they will not produce symptoms typical of the disease in the absence of the nemas.

FIELD OBSERVATIONS

Specimens of diseased small grains have been sent to this Laboratory frequently during the past 5 years. This has afforded an opportunity to evaluate the root rot disease-complex situation over a fairly wide area of the State. Since much of the small grain grown locally is planted as a fallow crop and therefore not harvested, our principal interest has been to determine if any correlation exists between the incidence and severity of disease in the fallow crop and that of the following tobacco crop. Considerable time has also been spent in an effort to determine from field observations if any correlation exists between soil type, seed treatments, and fertilizer practices (particularly the rate and frequency of application of lime and nitrogen) and the incidence and severity of disease.

The tobacco growers usually are not particularly interested in the welfare of the fallow crop and since the grain growers have an established program of treatments and rotations, it has been extremely difficult to obtain a productive type of cooperation in the field. The program of soil treatment on a cooperative basis is too recent to yield reliable data.

Under our conditions, root rot disease-complex of small grains is more severe on lighter soils. In a sense, such a situation is to be expected as such soils are usually included in a small grain-tobacco rotation, thus affording a year-around source of food for the nematodes. On those farms planted predominantly to small grains, the general build-up of disease appears to be more gradual.

Field observations also indicate that the severity of the root rot disease-complex may be influenced by seed treatment. The mercury compounds, in general, tend to reduce the incidence and severity of the disease more than do those treatments containing no mercury.

Our most recent field observations on fertilizer practices were made on a farm containing 150 acres of wheat and 75 acres of barley. In those fields which had not been limed within a 2-year period, root rot disease-complex was severe. Fields that had not been limed within the same period, but had received heavy applications of phosphate, were moderately attacked; while fields of both barley and wheat that had been heavily limed the preceding year were only slightly affected. These observations were made during fairly late fall. Observations made on the same fields during early spring, following a 2-week snow cover, indicated no apparent differences between the treatments listed above. All fields were severely affected and losses in stand were heavy.

Other observations indicate that high nitrogen applications noticeably reduce the severity of root rot disease-complex during the first season of its application.

Such observations may not be conclusive, though they have proved consistent over a period of several seasons. Certain practices, including those listed above, give only temporary relief as evidenced by the fact that later crops on the same fields and with the same treatments are often severely damaged by root rot disease-complex. A possible explanation for this anomaly, partially borne out by laboratory observations, is that well nourished plants may produce roots and root generation more rapidly during a given season than the existing nema population can destroy. During the period of apparent control, however, the nema population apparently is built up rapidly in response to an increased food supply and the succeeding crop suffers accordingly.

LABORATORY OBSERVATIONS

The basis of laboratory observations was work done in the greenhouse with infested soils from grain and tobacco fields. Temperature relations received most attention but a few experiments were run on pH levels

(the latter induced principally by high calcium), moisture, and soil amendments. Pertinent data from the tobacco root rot disease-complex studies, which were being run concurrently, were drawn on freely.

Under our conditions, maximum root mutilation developed, other conditions being equal, under conditions of relatively low soil temperatures. Soil temperatures ranging from 68° F. to 73° F. were conducive to maximum feeding by the nemas as evidenced by the severity and patterns of root mutilation. Root degeneration was not excessive at these temperatures. Temperatures below this range were not investigated but judging from field experiences the nemas are voracious feeders at temperatures considerably below 68° F. When soil temperatures were raised to 75° F., and higher, many roots in heavily infested soil escaped severe mutilation. Those roots which were already mutilated at lower temperatures, however, rotted rapidly at higher temperatures, thus indicating the influence of secondary invaders. As the soil temperatures were raised the nemas infesting the roots tended to slacken their feeding cycle and to intensify their reproductive cycle.

In the greenhouse where soil temperature was controlled, root mutilation was significantly more severe in high calcium soils than in low calcium soils. Relative pH readings of such soils did not satisfactorily explain such differences.

Relative moisture content of soils, under conditions of soil temperature control, also exerted a significant influence on the severity of root mutilation. The actual moisture level of the soil, however, did not appear to be more significant than the moisture holding capacity of the soil. In this phase of the work an effort was made to distinguish between the progress of root mutilation and the actual expression of disease symptoms.

In soil flats containing highly infested field soils, severely diseased oat plants made remarkable recovery in those flats to which 10 per cent of DDT (Dichloro-diphenyl-trichloroethane) by weight had been added, whereas those plants reset into untreated soil continued to decline and ultimately died without setting grain.

DISCUSSION

Root rots of small grains have promoted many productive investigations in recent times which have indirectly contributed much toward a better understanding of certain complexities involved. Perhaps no disease is as simple as the relationship between a single parasite and its host and certainly any serious consideration of root rots of crop plants must take into account the dynamic complexities and interactions operating between the root system and the rhizosphere. Since the meadow nemas, as a group, maintain representatives in practically all soil types and tend to play a significant part in the initiation of root troubles in a wide variety of crop plants, it seems they should be accorded much more attention in the future than they have had in the past.

SUMMARY

Small grains affected by root rot disease-complex are unthrifty, stunted, pale in color, and typically they fail to tiller. Older leaves of affected plants exhibit varying color patterns from pale green through bronzing to lemon yellow. When young plants are attacked the leaves become pale and flaccid, and many ultimately shrivel and die. Moderately and severely diseased plants are commonly "heaved" from the soil during periods of freezing and thawing, but it is not uncommon for such plants to be uprooted in early fall and late spring. Stand losses often are severe, affected fields showing bare patches of varying sizes. Moderately and severely affected plants are unproductive.

The root systems of diseased plants, when washed and viewed under magnification, show more definitive symptoms. The earliest indication of root disease is the presence of watersoaked lesions within the cortex of the feeder roots. These lesions undergo rapid color changes, attended by a loosening and slipping of segments of the cortex in a sleeve-like fashion which exposes the woody cylinder.

Leaf bases and young leaves within the crown of affected plants are invaded also and some are actually severed from their attachments.

Root rot disease-complex of small grains has been found to be initiated by the feeding habits of members of the meadow nema group, *Pratylenchus pratensis, Panagrolaimus subelongatus, Paraphelenchus pseudoparietinus,* and a *Ditylenchus sp.* In time and with rising soil temperatures other biologic agents enter injured tissues, both bacteria and fungi, and extensive root rotting occurs.

Control of root rot disease-complex of small grains has not been accomplished but soil fumigation in conjunction with development of small grains that will produce vigorous root systems would appear to have merit.

VIRGINIA AGRICULTURAL EXPERIMENT STATION,
TOBACCO RESEARCH LABORATORY,
CHATHAM, VIRGINIA.

ROOT ROT DISEASE-COMPLEXES OF TOBACCO IN VIRGINIA. I. BROWN ROOT ROT[1]

WILBERT A. JENKINS

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Brown root rot of tobacco has been known since 1916 when it was reported from the Connecticut Valley, Wisconsin, Maryland, and Kentucky (5, 6). Undoubtedly the disease occurred earlier than this but had previously been confused with other diseases of a similar nature. Johnson (5, 6) has published two classic papers on the subject and several other investigators have added valuable contributions.

Due to the widespread occurrence of brown root rot, as well as to the published work available, most symptoms of the disease are now quite well known to those interested in tobacco as are, also, several conditions which influence the incidence and intensity of the disease.

Earlier work (3, 5) sought to demonstrate a fungus or bacterial pathogen but these efforts proved fruitless. Lehman (7) published an excellent description of a "new" brown root rot disease of tobacco from North Carolina with which *Tylenchus pratensis* de Man (*Pratylenchus pratensis* (de Man) Filipjev) was associated. Although the causation of the disease was not proved experimentally, there seems little doubt but that the meadow nema was regarded as a primary parasite by this investigator. He also determined that relatively high calcium levels in the soil, as measured in terms of rates of application of lime and pH determinations, favored the intensity of the disease. Lehman concluded that this disease and that described earlier from Wisconsin were not of the same origin, his premise being that the intensity of brown root rot diminished with successive crops of tobacco in Wisconsin, whereas the intensity of the "new" brown root rot increased in intensity with successive tobacco crops in North Carolina. Steiner (9) supplemented the above report by publishing a taxonomic determination of the nemas associated with root rots of tobacco, noting that tobacco was a new host for *T. pratensis*.

A vast preponderance of the published work relates the causation of brown root rot to certain non-living soil constituents arising directly or indirectly from decomposition of residues from preceding crops (2, 5, 6, 10). This interpretation of the etiology, though admittedly tentative, evoked surprisingly little controversy considering the rather abstruse nature of the hypothesis until other investigators again sought to prove the relationship of a fungus pathogen (8).

Work under way at this Laboratory since 1941 definitely established brown root rot as one of the root rot disease-complexes initiated by the feeding habits of members of the meadow nematode group and resulted in the publication of a preliminary report (4). Partial confirmation of our

[1] Published with the approval of the Director, Virginia Agricultural Experiment Station, as Scientific Paper No. 135 from the Section of Botany and Plant Pathology.

results has since been published (1, 11). A more complete exposition of the results accomplished at this Laboratory forms the basis of the present report.

SUSCEPTS

Brown root rot is known to affect the several types of tobacco generally grown in Wisconsin, the Connecticut Valley, Kentucky, and Maryland (5, 8). Such types as dark fire-cured and burley are known to be affected in Virginia, Tennessee, and Kentucky while flue-cured types are affected in Virginia, North Carolina, South Carolina, and Georgia. There are persistent reports of brown root rot in flue-cured tobacco in the Province of Ontario, Canada, and in shade grown tobacco in Florida, as well. Other

FIG. 1. Field view of Yellow Special strain of tobacco affected by root rot disease-complex. The field was adequately cultivated but the plants never attained sufficient growth to shade out the grass and weeds. Note the "cabbage-like" growth, with wilting, stunted, bony leaves. Two successive crops were complete failures on this field.

solanaceous crop plants such as tomatoes, potatoes, eggplant, and pepper, as well as several leguminous and graminaceous crop plants were reported to be more or less severely affected (6). Our investigations confirm this diverse host range in so far as members of the above list have been investigated. In addition, we have found crab grass (*Digitaria* spp.) and *Buxus* spp. (boxwood) to be seriously affected and *Vitis* spp. (common bunch grapes) and corn (*Zea mays*) moderately to severely affected. Since members of the meadow nema group are universal in distribution and are voracious feeders, it is highly probable that a study of a vast number of root rot disease-complexes, which at present are attributed to other causes, may in time contribute to an extension of the list of suscepts for brown root rot.

SYMPTOMATOLOGY

One of the outstanding above-ground symptoms of brown root rot in the field is its resemblance to the disease generally known as black root rot. It is unusual to find all plants in a given field severely affected, though this sometimes happens (Fig. 1, Fig. 3, A). As a rule, symptoms are severe in areas of varying size within a given field, whereas sections of the same field may appear only moderately if at all affected. Quite often severely affected plants appear individually and at random throughout a field.

FIG. 2. Typical symptoms of root rot disease-complex on young tobacco in the presence of adequate soil moisture. Note the severe wilting of the leaves and the beginning of "cabbage-like" growth.

Plants severely attacked have symptoms of severe drouth even in the presence of adequate moisture (Fig. 2). Such plants develop a "cabbage-like" type of growth, entirely uncharacteristic of flue-cured types. When seedlings are attacked they generally develop wiry stems and rarely recover. During periods of drouth or excessive water loss, even moderately affected plants develop symptoms of a severe type. Plants thus affected become stunted throughout and the leaves tend to undergo successive periods of wilting. It is not unusual for the entire distal portions of such

leaves to burn off completely, thus ruining a third to half the leaf area. Leaves of such plants become dwarfed and the larger vascular elements tend to stand out in coarse rib-like fashion (Fig. 1). Pronounced flagging of such leaves is common, followed by premature yellowing and rim-firing of the older leaves (Fig. 3, A and B). Needless to say, such leaves must be harvested green, if at all, thus resulting in a poor quality product and heavy loss to the grower.

Brown root rot symptoms are more definitive on the root systems of affected plants than on the above-ground portions. Here the true nature

Fig. 3. Typical field symptoms of root rot disease-complex on mature tobacco. A. Portion of a 4-acre field of Bonanza which yielded about 300 sticks of tobacco that would not cure. B. Close-up view of severe rim-firing and tip burning of the older leaves.

of the disease may be ascertained. Severely affected plants may be easily pulled from the soil by midsummer because of almost complete destruction of the root systems. Moderately affected plants exhibit varying stages of root survival, but generally the individual roots are discolored, stubby, and surviving roots are grouped near the soil surface (Fig. 4). Under magnification, affected roots show varying degrees of mutilation consisting of cortical lesions varying from pale yellow to almost black. Such lesions generally result in complete girdling of the feeder roots followed by loss of the cortical tissues through sloughing off (Fig. 5, A, B). The incidence and severity of root decay depends on such factors as soil tempera-

ture, moisture, calcium level, and the population of biologic associations in the rhizosphere. The above mentioned factors also influence the color of the deteriorating roots so that brown root rot is not an altogether descriptive designation for the disease.

A considerable amount of field work has been accomplished on brown root rot at this Laboratory but our most reliable data have been secured in the greenhouse and laboratory under controlled conditions.

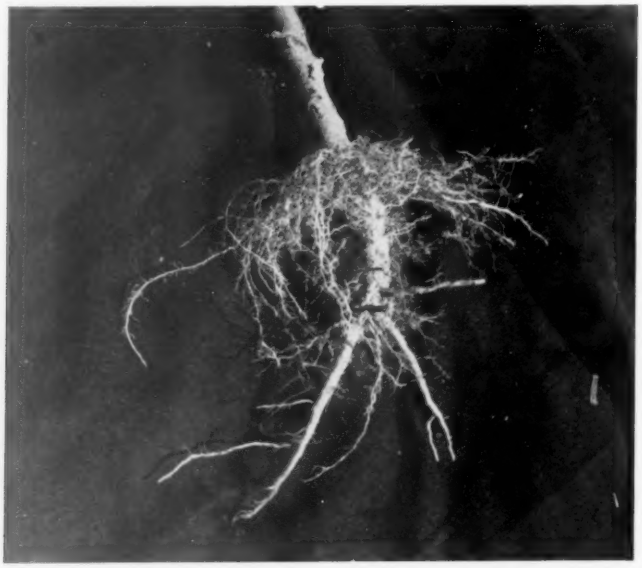

Fig. 4. Root system of a plant affected with root rot disease-complex. Note the "brush" of roots remaining near the soil line and the bare roots below. Even the roots near the soil line show evidence of severe mutilation.

MATERIALS AND METHODS

The basic results of the present investigation were secured from soils taken from fields that had produced essentially worthless crops of tobacco over a period of several years because of brown root rot. Preliminary examinations had shown these soils to be free from *Thielaviopsis basicola* (Berk.) Ferraris, but heavily infested with meadow nematodes, of which *Pratylenchus pratensis* (de Man) Filipjev was the dominant component of the population. Soils were also taken from the black root rot plots at this Laboratory which have consistently produced stunted crops of tobacco over a period of 15 years when planted to susceptible strains. This soil was known to be heavily infested with certain members of the meadow nematode group, except *P. pratensis*, as well as with several different fungi, including *T. basicola*. Other soils were taken from the agronomy plots at this Station on which profitable crops of tobacco have been grown since 1936 and from which there had been no complaint regarding yield and quality. This latter soil had been cropped continuously with small

grain-tobacco rotations, the small grain being used as a winter cover crop. For benefit of later discussion, the soil from the brown root rot fields is designated I and is Appling type; soil from the black root rot plots is designated II and is Cecil Clay Loam type; while soil from the agronomy plots is designated III and is Granville type.

These soils were used in one-gallon, glazed pottery crocks, suitably set up for proper drainage and aeration of the soil. Fertilizer, 3–9–6 analysis, was used at the same per plant rate as in the field. Check lots of all soils were sterilized within the crocks in an autoclave at 20-lb. pressure for 2 hours. Plants grown in pots until well rooted at greenhouse temperatures were transferred to constant temperature tanks equipped with both re-

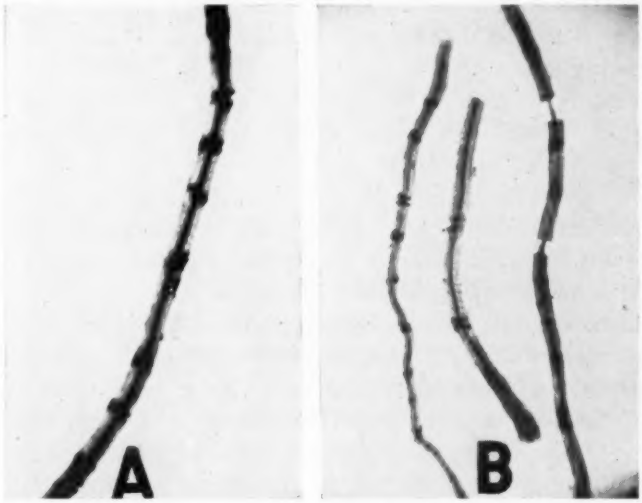

Fig. 5. Photomicrographic views of mutilated feeder roots from plants affected with root rot disease-complex. A. Extensive girdling of feeder roots and discoloration of tissues by biologic associates, in this instance, *Thielaviopsis basicola* among other fungi. B. Transition between girdles and sloughing of the cortical tissues.

frigeration and heating units. By means of dual thermoregulators, the soil temperatures were maintained within 1° F. (±) of a selected point over a temperature range of 32° F. to 120° F. Air temperature was controlled through ventilation of the greenhouse and soil moisture was regulated manually. Since the tanks were not enclosed, the above-ground portions of test plants had benefit of full sunlight, conditioned only by the glass roof of the greenhouse. By means of auxiliary lighting, the photoperiod was maintained equivalent to that of early spring conditions in the field. Seedlings were grown to transplanting size in steam sterilized sand flats. The test strains of tobacco were Yellow Special (highly tolerant to several root rot disease-complex manifestations and generally considered highly tolerant to black root rot), Yellow Mammoth, and White Stem Orinoco (both highly susceptible to root rot disease-complexes, including black root rot).

EXPERIMENTAL RESULTS

Soil temperature studies. In an effort to duplicate the soil temperatures prevailing in this area at the time the crop is normally set into the field, seedlings of each test strain were grown at several different temperatures, and some were started at one temperature and later subjected to a higher temperature. At the end of a 10-day period, plants were removed from soils maintained at approximately 68° F., the root systems washed thoroughly and examined under a dissecting microscope. Root samples were also preserved for further study. In some instances, random lots of seedlings were reset into the crocks and grown for additional intervals in order that the course of development could be studied at later dates. Additional plants were removed from all soils at varying intervals following the 10-day period so that the progress of events could be traced throughout the growing season.

When examined within 10 days following transplanting, numerous uncomplicated lesions were found on all young roots regardless of soil type and variety. The earliest distinguishable lesions were present on practically all portions of the roots except in the growing points and in the relatively mature tissues. As a rule, most lesions and the more severe early symptoms of root mutilation were present in the region of elongation. Lesions within the growing points were not seen.

The lesions are initially devoid of pigment but may appear slightly elevated and watersoaked under magnification. These are the lesions which yield nematodes in the largest numbers. Very soon after formation a majority of the lesions break open because of separation of the injured cortical tissues and the rupture extends into the cambial region. Probes inserted into young lesions, as well as transverse sections, confirm the observation that the nematodes penetrate through the cortex and into the cambial layer. This indicates that the nematodes may feed within the cambial tissues. Observations also indicate that the lesion is initiated by the insertion of the nematode stylet and that further rupture of the injured area may be due to high cellular tension existing at the point of penetration.

With age, the lesions become progressively more discolored. The earliest color change is to pale cream or pale yellow, finally developing a reddish to black appearance, apparently depending somewhat on the nature of the biologic successions. Lesions are found quite often over the potential exit of a secondary root or in the crotch of a lateral root. Most lesions eventually result in the separation of segments of the cortical tissue from the woody cylinder at the cambium. This condition is followed by sloughing off of the cortical tissues in a sleeve-like manner. Lesions uncomplicated by root rotting associates generally cause affected roots to shrivel and die, particularly if the root is a feeder root and lesions are numerous. Lesions formed on older root tissues often heal over, though

the callus remains evident as prominent scar tissue. This activity results in extensive root pruning. Continuation of root generation coupled with root pruning is responsible for the stubby appearance of affected root systems. Since the feeding habits of the nematodes are markedly affected by temperature, as will be brought out later, the higher temperatures near the soil line may afford a measure of protection for adventitious roots developed in this area, thus explaining the survival of some roots near the soil line.

At temperatures of 73° F. to 80° F., initially, lesion formation is accompanied by several biologic associates other than nematodes, which complicates the picture. Under such conditions, extensive root rotting may occur rather early. Plants started at 68° F. and then subjected to higher temperatures (75° F. to 80° F.) give us a better understanding of what is happening.

In soil I, the nematode which is dominant at 68° F. is also dominant at temperatures between 73° F. and 80° F. Lesions are formed in a measured pattern at 68° F. (Fig. 4) and this pattern is continued at higher temperatures. At temperatures above 75° F. there is a distinct tendency toward more longitudinal movement by the nematodes in affected roots, however, and the reproductive processes of the nematode apparently are accelerated. Root rotting also is enhanced by the higher temperatures.

In soils II and III the entire picture is altered by elevation of the soil temperature. At 68° F. many lesions are formed but the pattern is variable, i. e., the lesions do not appear at measured intervals along the roots. At the same time, several different nematodes are present in the soils with little evidence that any one species is dominant. The picture is even more confusing with successive crops of tobacco because the specificity of the nematode population fluctuates. Under these conditions, there appears to be a succession of nematode forms resulting in specific alterations in the nematode complement of the soils. When the temperature of these soils is raised into the range of 75° F. to 80° F., essentially all nematode feeding ceases. Eggs are laid but for some reason new penetrations diminish in frequency and the plants tend to recover. The roots that were badly mutilated at 68° F. decay rapidly at high temperatures, but the rotting does not spread to new roots.

In soil II, *Thielaviopsis basicola*, among other fungi, grows luxuriantly on, and adjacent to, the lesions and sloughing cortical tissues, but as the soil temperatures are elevated to the point where nematode feeding diminishes, new loci of infestation by *T. basicola* diminish proportionately.

The above-ground portions of all varieties were stunted severely on soils I, II, and III at 68° F. At temperatures of 80° F. or higher, all tobacco strains on soil I remained severely stunted, but on soils II and III the strains were easily separable on the basis of tolerance. All strains attained more height on soil III than on soil II at 68° F.

At 68° F. on soil II, Yellow Special attained significantly more height than did Yellow Mammoth or White Stem Orinoco, but it did not approximate the height of the check thus indicating that the strain was stunted by root mutilation. At temperatures of 80° F. and higher, Yellow Special attained significantly more height than did either of the other strains under test. At least some portion of this response was due to the ability of Yellow Special to continue root generation, whereas the other two strains showed evidence that they were incapable of sustaining a high rate of root generation under the same conditions.

All strains grew normally on the check (sterilized) soils of all types. There was very little root mutilation in the checks and the small numbers of nematodes found were indicative that a slight infestation was introduced by splashing water or by air currents.

It thus appears that injury at all soil temperatures results from an unbalance between the rate of root mutilation by the nematodes and the rate of root generation by the host. At low soil temperatures (68° F.) the nematodes are voracious feeders. Since root generation is comparatively slow at such a temperature, the feeder roots are destroyed faster than new roots are generated, and the result is stunting of the plants. At higher temperatures, the reproductive phase of the nematode is accelerated and feeding slows down. Whether or not the plants generate roots faster, the plants tend to recover because of a more favorable balance. The exception to this general statement is found in the case of plants affected by *Pratylenchus pratensis*. In such plants there is no recovery or it is only slight.

Studies with air-dried soils. During the early phases of this investigation, soils were collected from many different fields where tobacco had symptoms of brown root rot. Often the soils became completely air-dried before they were used. It was soon noted that such soils consistently failed to induce typical symptoms of brown root rot when seedlings were set into them. Since this experience was in accord with Johnson's findings (5), no effort was made to elaborate on this phase of the work. It was determined, however, that *Pratylenchus pratensis* is more susceptible to destruction from drying than are certain other nemas associated with it in many tobacco soils collected in eastern Virginia and eastern North Carolina.

Studies with chemical amendments. Having determined the probable causation of brown root rot, together with several climatic factors favoring its severity, it was thought that practical control of this and other root rot disease-complexes might be achieved by affording transient protection to susceptible strains of tobacco long enough for seedlings to recover from the shock of transplanting and generate a functioning root system. This idea was based on the hypothesis that a tobacco plant might create a more favorable balance for its feeder root system through root generation if the rhizosphere were rendered temporarily free of nemas at the time of transplanting.

Chemical treatments were used as dust and liquid formulations and the root systems of the plants were plunged into the chemicals immediately before being set into the soil.

Of the many chemicals and formulations of each that were used, only a very few satisfied the conditions for which they were intended. For instance, a vast number of the materials containing mercury were too toxic to the root systems even though they proved highly effective against the nemas. Benzine hexachloride (Hexachlorocyclohexane) was in the same category with mercury. Varying formulations of DDT (Dichloro-diphenyl-trichloroethane) from 10 per cent to 50 per cent by weight gave excellent control in certain fields and in the greenhouse. In other fields, however, DDT treatments were not effective, probably because the effects were too transient.

Limited information was secured in greenhouse cultures indicating that a high calcium level in the soil definitely favors brown root rot. This effect is particularly noticeable in the crop following that to which the application was made. High nitrogen levels gave very similar results. In the greenhouse experiments, the calcium level was roughly equivalent to an application of 150 lb. lime per acre to ordinary tobacco soil and the nitrogen level was roughly equivalent to a side dressing of 50 lb. nitrate of soda per acre on ordinary tobacco soil. Such information means little by way of field application since conditions in the field soils as influenced by past practices would vary more widely.

ETIOLOGY

Isolations from very young lesions on root systems grown on all soil types at 68° F. were either negative or the inconsistencies and variation among the isolations were so prevalent as to preclude the possibility of a primary bacterial or fungus parasite when bacteriologic methods were used. On the other hand, members of the meadow nema group were abundant in the very young lesions when the proper method of demonstrating their presence was used. Representatives of all fungus and bacterial isolates were incapable of inducing symptoms of brown root rot when used as inoculum, except in the presence of members of the meadow nema group.

In material from soil I grown at 68° F., *Pratylenchus pratensis* is the nema species found almost exclusively. At higher temperatures in the same soil, *P. pratensis* continues to be the dominant nema present, though other nemas as well as fungi and bacteria may be readily isolated from decomposing roots.

Materials from soils II and III grown at 68° F. yielded relatively large populations of nemas of several types, including *Ditylenchus sp.*, *Aphelenchoides sp.*, *Panagrolaimus sp.*, *Aphelenchus sp.*, and *Acrobeloides spp.* In these soils no single species predominated at any temperature. Bacterial and fungus isolations were negative from very young lesions. As the lesions began to rupture and adjacent tissues deteriorated, numerous

fungi and bacteria were isolated. As in soil I, isolations from soil II and III varied in almost direct proportion to the time interval the roots had been exposed. During the initial 10-day interval comparatively few species of fungi and bacteria were isolated, but at successive intervals the numbers increased. Such a pattern of increase might readily indicate normal biologic succession. For instance, in soil II, the earliest fungi isolated were species of *Fusarium* and *Pythium*, but as time intervals multiplied, *Mucors*, *Macrophomina phaseoli*, *Thielavia basicola*, and *Thielaviopsis basicola* were readily isolated.

When the temperature of soils II and III was raised to 80° F. and higher, the nema population began to fluctuate widely, finally resulting in an entirely different nemic population from that originally present. At these higher temperatures feeding by the nemas (as evidenced by lesion development) ceased. At the same time, *Thielavia* and *Thielaviopsis* disappeared from the roots, though *Thielaviopsis* could still be readily isolated from the soil by appropriate methods (12).

DISCUSSION

The etiological aspects of brown root rot of tobacco are no longer obscure, but a consideration of the available data develops a concept of plant disease which is difficult to discuss except on a broad basis.

An evaluation of the data which have accumulated through work accomplished under controlled conditions demonstrates rather conclusively that brown root rot of tobacco must be classified as a root rot disease-complex. Our experiences demonstrate that the disease in this area is initiated by the feeding habits of members of the meadow nema group and that one of these nemas, *Pratylenchus pratensis*, is alone capable of inducing symptoms typical of the disease.

In our work with various strains of flue-cured tobacco grown under controlled conditions on soils known to produce consistent symptoms of brown root rot in the field, very young lesions yield essentially negative isolations, except for *Pratylenchus pratensis*, when the soil temperature is maintained at 68° F. At higher temperatures, isolations of fungi and bacteria from deteriorating roots are too inconsistent and variable to indicate more than normal biologic succession in decomposing tissues. When representatives of these isolations were reinoculated into clean soil, no symptoms of brown root rot develop on tobacco grown in it; whereas the disease always develops in the presence of *P. pratensis*.

Soils taken from fields in this area invariably harbor large populations of nemas. A vast proportion of this nema population feeds on living roots of tobacco and other crop plants, as well as weeds, growing in the soils. Since the nemas prefer succulent tissues, it is only natural that the feeder roots will suffer most, regardless of the crop in question. Such a situation brings very sharply into focus the problem of a potential reduction in vegetative vigor in the exposed crop with consequent reduction in yields

and quality. This may and undoubtedly does occur over wide areas even in the absence of specific symptoms on the above-ground parts of affected plants. The implications of such a situation are tremendous both from the agronomic and pathologic standpoint, for complications arising from mutilation of the feeder root system of a crop plant may vary all the way from symptoms of nutritional deficiencies to those of an epiphytotic disease.

The matter of biologic associations has merely been mentioned, not explored. Certain nemas may function both as primary invaders and as carriers of biologic associates, some of which may, following introduction, be classified as primary parasites and a majority of which may attack tissues already weakened by mechanical mutilation. Thus transient diseases may be due to nemas which are non-toxic and which respond in their feeding habits to very narrow temperature ranges.

The physiologic or toxicity effects of nema feeding on tobacco roots has not been investigated but observational evidence suggests that certain species, among these being *Pratylenchus pratensis*, are highly toxic to certain crop plants over and beyond the matter of root mutilation. Other forms which show little evidence of toxicity undoubtedly bring about mild to severe nutritional deficiencies in crop plants by mechanical destruction of roots, while others may act as carriers of saprophytic or parasitic associates, perhaps including some of the viruses.

Another very interesting aspect of root rot disease-complex brought out by this work is the fact that tobacco strains of different genetic constitution often respond differently to nema invasion. The best evidence for this opinion rests on comparative measurements of plant height, for our results show that a given strain may suffer significantly less stunting of the above-ground parts than another although the root systems of both may be about equally mutilated. Where soil infestation by *Pratylenchus pratensis* occurs, however, the situation is basically different. We have found general indications that a strain of different genetic constitution will often produce a satisfactory crop in the presence of *P. pratensis* provided this strain is being grown on the infested soil for the first time, i.e., following a long period of culture of some other genetically different strain. These results appear to follow the principle of adaptive feeding by the nemas. In time, one would expect the nemas to become adapted to any new introduction.

Calcium and nitrogen levels appear to exert both a direct and indirect effect on the nema populations. Calcium, for some reason, appears to favor the nemas directly, whereas both calcium and nitrogen encourage the development of extensive root systems which in turn might be expected to influence the increase and accommodation of larger nema populations. That this may be true seems to be borne out by the fact that brown root rot and other root rot disease-complexes of crops appear to be more severe on crops following those which received supplemental applications of calcium and nitrogen.

Finally, host adaptation would appear to offer a valid explanation for variations in intensity of brown root rot of tobacco in different parts of the country as related to cropping practices. Our experience with members of the meadow nema group indicates that members of the grass family are more natural hosts of the group as a whole than is tobacco. Consequently, in the flue-cured tobacco belts where successive tobacco crops are grown for long periods on the same fields, the nemic populations consist of large numbers of highly adapted individuals which persist in accordance with the cropping practices. In other sections of the country where tobacco is grown periodically following more or less lengthy rotations with grasses and other crops, large populations of nemas undoubtedly develop and persist but the adaptive process toward tobacco is not so acute. Since, under the latter conditions, grasses would appear to be the favored host, the nemic population on a given field would be expected to diminish with each successive tobacco crop grown on a given field, at least until such time as that population increase could be initiated and sustained by adapted individuals. By host adaptation is meant the ability of the nema to reproduce successfully on a given host, not merely the facility of feeding on it.

SUMMARY

Studies of tobacco root rots in the field and under controlled conditions in the greenhouse and laboratory since 1942 offer conclusive evidence that brown root rot should be classified as one of the root rot disease-complexes.

Tobacco affected by brown root rot has unmistakable symptoms of drouth injury. In general, affected plants do not grow properly following transplanting, either in certain areas within the field or throughout the field. The leaves of affected plants undergo alternate periods of wilting and recovery during early stages of the disease, but as the season progresses many leaves fail to regain turgidity wholly or in part, resulting in stunted plants bearing coarse, stunted leaves with varying degrees of tip burning and rim firing. Severely diseased plants frequently have symptoms of plant food deficiencies.

Brown root rot symptoms are more definitive on the feeder root system which typically becomes mutilated to such an extent that it can no longer adequately perform its function. Lesions, as seen under magnification, are at first watersoaked to pale yellow and finally brown to black. The color changes generally follow rather extensive cortical fissures (girdles) which extend into the cambial zone and result in extensive sloughing of the cortex. Root rotting often accompanies root mutilation but varies in extent and severity with such factors as soil temperature, moisture, calcium level, and biologic associates in the rhizosphere. Root mutilation precedes root rotting and may, alone or in conjunction with the latter, result in an inadequate feeder root system.

Under our conditions, brown root rot of tobacco is initiated by the

feeding habits of members of the meadow nematode group, of which the true meadow nema, *Pratylenchus pratensis* (de Man) Filipjev consistently produces severe symptoms.

Adequate control of brown root rot has not been attained. Such measures as supplementary nitrogen applications, rotations with tobacco varieties of different genetic constitution, and hilling the soil high about the bases of plants have afforded temporary benefit to the current crop. Soil fumigation studies recently begun appear to offer more permanent control when used in conjunction with varieties of tobacco developed to produce more vigorous root generation.

VIRGINIA AGRICULTURAL EXPERIMENT STATION,
TOBACCO RESEARCH LABORATORY,
CHATHAM, VIRGINIA.

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THERAPEUTIC TREATMENTS FOR RUSTS

C. E. Yarwood

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Several exceptions are known to the common generalization that diseases caused by rust fungi are not subject to control treatments after infection has occurred. Newton *et al.* (3) found that catechol injected into wheat leaves 4 days after inoculation with rust, reduced subsequent rust development by about 50 per cent. Gassner and Straib (2) reported that sulphur dust was effective in reducing cereal rust when applied up to 10 hours after inoculation and kainite up to 48 hours after inoculation. Gassner and Hassebrauk (1) discovered that overnight immersion of leaves in sodium sulphide solutions killed cereal rust infections up to 3 days after inoculation. Sempio (7) found that temperatures of 34° to 36° C. for 2½ days completely killed bean rust mycelium when the treatment was applied 4 days after inoculation. Ogilvie and Brian (5) developed a practical control of mint rust by treating the cuttings for 10 minutes in water at 112° F. but the nature of the control is not clearly set forth, and Niederhauser (4), who confirmed the success of the method, believed that control resulted from the killing of the uredospores and not from the killing of the rust mycelium in the tissues as it is to be inferred from the results of Brian and Ogilvie. Parker-Rhodes (6) used 15 minutes immersion in water at 40° C. for the eradication of two wheat rusts, but no details of rust development are given. Yarwood (9) reported killing of 5-day-old uredial pustules of bean rust, snapdragon rust, and sunflower rust without host injury by exposure of the plants to the vapors from lime sulphur solutions, or from dilute hydrogen sulphide gas. Zaumeyer and Goldsworthy (11) state that liquid lime sulphur, chlorinated naphthoquinone, and disodium ethylene bisdithiocarbamate were effective in eradicating 24-hour infections of bean rust. The present report presents quantitative details of rust therapy by the above and other methods.

MATERIALS AND METHODS

The uredial stages of sunflower rust (*Puccinia helianthi*) on variety Mammoth Russian, bean rust (*Uromyces phaseoli*) on variety Pinto, snapdragon rust (*Puccinia antirrhini*) on varieties of cultivated snapdragon, and mint rust (*Puccinia menthae*) on spearmint were used in these tests. The rusts were collected in the San Francisco Bay region and all tests were made on plants growing in 4-inch pots in the greenhouse at Berkeley, California. Pinto bean plants with paired primary unifoliate leaves suitable for inoculation in 8 to 12 days from seeding were best suited for these tests and were most used. The plants were inoculated by spraying them with a spore suspension and incubating them overnight, usually about 14 hours, in moist chambers with a prevailing temperature of about 17° C.,

and then placed on the greenhouse bench. Tests of eradicant (therapeutic) treatments were usually made at 4 days after inoculation, at which time the pustules first became evident, but shorter and longer infection periods were also used.

To test the eradicant action of dry air, as a measure of the incubation (in the sense of Whetzel) period under conditions of these trials, inoculated plants, placed in moist chamber incubators at inoculation, were removed from the moist chambers at varying times after inoculation and placed on a turntable in the greenhouse, where the leaf surfaces usually dried in about 30 min. Soon after the plants had dried, they were returned to the greenhouse bench.

Spraying was done with a No. 15 DeVilbiss atomizer attached to 35 lb. air pressure. For ordinary coverage applications the nozzle was held about 8 inches from the leaves to be sprayed, but for the penetrating or water soaking applications the nozzle was held at about $\frac{1}{2}$ inch from the lower leaf surface. A spreader, 0.05 per cent B1956, a proprietary form of phthalic glycerol alkyl resin, was used in all cases where a spreader is indicated.

Infection was normally measured by counting the living pustules per square centimeter at about 10 days after inoculation. With the beans, untreated check leaves were the twin leaves opposite the treated leaves, except in the tests with dry air, when, as with all tests on all hosts other than bean, the check leaves were on separate plants. Infection on the checks ranged from 20 to 100 pustules per sq. cm. and percentage control was calculated as

$$\frac{\text{Pustules per cm.}^2 \text{ on check} - \text{Pustules per cm.}^2 \text{ on treated} \times 100}{\text{Pustules per cm.}^2 \text{ on check}}$$

In a few cases, as in the hot water treatments, practically all pustules in a given treatment reacted alike, eradication was total or nil, and intermediate values were estimated.

In trials of vapors, as those from lime sulphur solution and from mixtures of sodium cyanide and sulphuric acid, exposures were of two types. In most tests the leaf to be treated was placed in a 450-cc. fruit jar with a notch in the rim to accommodate the petiole. After the leaf lamina, still attached to the mother plant, was placed in the jar, the glass top with rubber seal was fastened on with a rubber band and the opening around the petiole was sealed with modelling clay. Plants with leaves in jars of this type were placed on a rotating turntable in daylight for the specified exposure period and then the leaf was removed from the jar and the plant returned to the greenhouse bench. In another type of exposure the pots of plants to be treated were placed in closed 120-liter cans in the dark and the sodium cyanide-sulphuric acid mixture in a jar was placed beside the plants, but with no provisions for forced air circulation.

Cyanide was produced by adding an equal volume of 20 per cent sul-

phuric acid to the required amount of 0.2 per cent sodium cyanide. It is assumed that all the cyanide was released as gas.

To test the therapeutic effect of hot water on bean rust and mint rust, infected leaves of potted plants were immersed in distilled water at specified temperatures and then the plants were returned to the greenhouse bench.

Hot air therapy was investigated only with snapdragon rust. Because of the low heat capacity of the incubators the introduction of potted plants markedly lowered the incubator temperatures, and an hour or so usually elapsed before the incubators reached their original desired temperature. Also, the incubator temperature only was measured, and the leaf temperatures would be less. For these reasons, the data on hot air therapy are considered less reliable than those of hot water therapy.

RESULTS

Dry air. Results of two trials in the greenhouse of the eradicant action of dry air for bean rust are presented in figure 1, A, and show values ranging from 100 per cent eradication in 2 hr. after inoculation to 0 per cent in 18 hrs. In two trials at 13° C. with sunflower rust, dry air gave complete eradication in 2 hr., 55 per cent in 6 hr., 25 per cent in 12 hr., and 0 per cent in 18 hrs. These values must be considered in relation to later results with fungicides, as they indicate that chemical treatments showed eradicant action long after dry air was ineffective.

Ordinary spray applications. Most spray applications are designed to cover the plant surface but not to penetrate the tissues. Such surface sprays, however, may give eradication of rust long after the fungus has developed beyond the stage where it can be eradicated by dry air. Results with 2 per cent rosin lime sulphur (8) on sunflower rust indicate that 100 per cent eradication was secured up to 16 hr. after inoculation, and that control decreased progressively to 0 at 90 hr. after inoculation (Fig. 1, A). This spray was therefore partially effective up to 77 hr. after dry air had no eradicant action. Other materials tested and results of a typical test 14 hr. after inoculation were: sulphur dust—5 per cent eradication, 1 per cent Bordeaux plus spreader—35 per cent eradication, 2 per cent lime sulphur plus spreader—86 per cent eradication, and 0.2 per cent copper resinate in emulsifiable pine oil—96 per cent eradication.

When plants treated in this manner were placed in a moist chamber after spraying, and the drying of the spray thus delayed, the eradication was more complete than when the plants were dried immediately after treatment. For example, in tests with sunflower rust at 18 hr. after inoculation, 2 per cent rosin lime sulphur gave 86 per cent eradication when the treated plants were dried immediately, and 100 per cent eradication when the plants were held in a moist chamber for 6 hr. after treatment. Unless otherwise mentioned, plants treated with eradicant sprays were held in a moist chamber for about 6 hr. after treatment.

When a spreader was added to any of the therapy sprays used, greater rust control resulted, presumably because the spreader facilitated penetration of the spray through the stomatal openings and into the intercellular spaces, even though the penetration did not reach the point where watersoaking of the tissues was apparent to the unaided eye. For example, 0.03 per cent copper sulphate without spreader gave 94 and 32 per cent eradication at 18 and 65 hr., respectively, but with a spreader gave 98 and

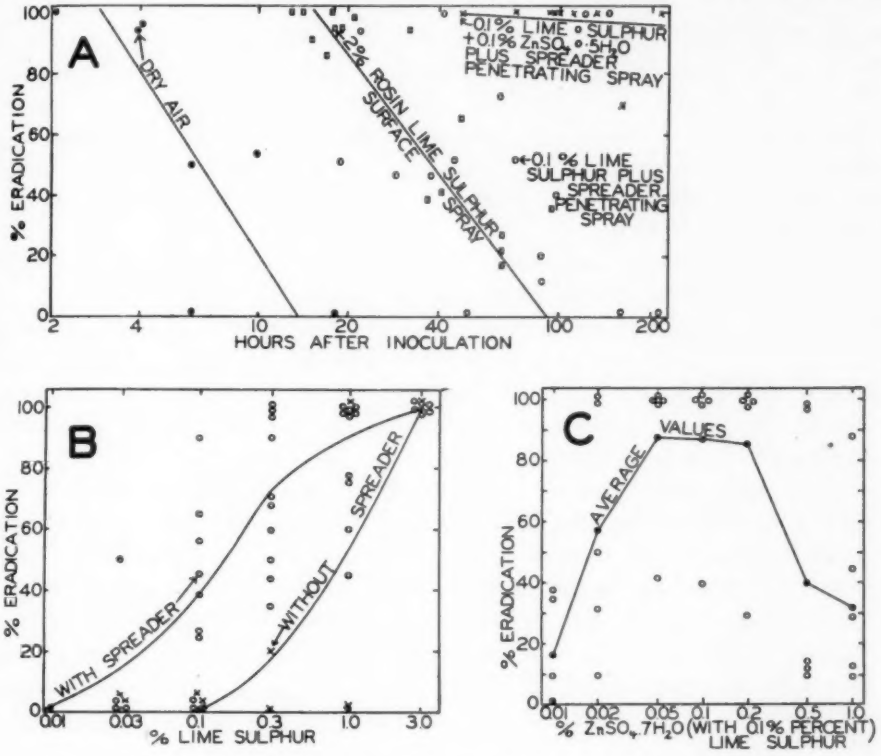

FIG. 1. A. Eradicant action of dry air for bean rust, rosin lime sulphur surface spray for sunflower rust, and lime sulphur and lime sulphur-zinc sulphate as penetrating sprays for bean rust. B. Effect of 0.05 per cent spreader on the eradicant action of various dosages of lime sulphur as penetrating sprays. C. Effect of varying dosages of zinc sulphate on the eradicant action of 0.1 per cent lime sulphur for bean rust.

74 per cent eradication at these same periods. A series of 8 trials with 0.1 per cent copper sulphate plus spreader followed by 6 hr. in the moist chamber over the period from 16 to 96 hr. after inoculation gave an average time-eradication response curve which could not be distinguished from that of rosin lime sulphur.

Penetrating spray applications. While ordinary spray applications on beans leave only a surface deposit, complete water soaking of leaves is readily attained by sprays, and is favored by high as compared to low impact pressures, morning application as compared to afternoon or night

applications, young leaves as compared to old leaves, and the use of a spreader as compared to the use of sprays without a spreader. Water soaking spray applications caused greater injury than surface applications, but injury was less when the treated plants were placed in a moist chamber until after dark, and then returned to the greenhouse bench, than when allowed to dry in the sun immediately after spraying.

Copper sulphate, lime sulphur, and mixtures of lime sulphur and zinc sulphate were most studied. Of these, copper sulphate was poorest, and applications of 0.01 to 0.1 per cent gave 70 to 90 per cent eradication of bean rust at 40 to 114 hr. after inoculation. Dosages of 0.01 to 3.0 per cent lime sulphur with spreader (Fig. 1, B) gave eradication values which were approximately those of a normal dosage response curve. Lime sulphur without spreader (Fig. 1, B) was less effective than lime sulphur plus spreader except at the 3 per cent concentration, which gave complete eradication in all tests.

Results of trials of the effect of age of infection on eradication of bean rust with 0.1 per cent lime sulphur plus spreader are given in figure 1, A. Eradication from sprays applied 9 to 215 hr. after inoculation ranged from 0 to 100 per cent with no clear relationship to time. This concentration is near the critical lower dosage for eradication (Fig. 1, B), and it appears that some inadequately controlled factor was important in determining these variable results.

The effect of addition of zinc sulphate to lime sulphur is presented in figures 1, A and 1, C. In figure 1, A, it is shown that 0.1 per cent lime sulphur plus 0.1 per cent zinc sulphate plus spreader gave 100 per cent eradication when applied 48 to 215 hr. after inoculation in 7 out of 8 trials, and was therefore more effective and more consistent than lime sulphur without zinc sulphate, an observation also supported by trials of this mixture as a protective spray (10). The effect of varying the concentration of zinc sulphate from 0.01 to 1 per cent is shown in figure 1, C, and it is clear that there exists a broad optimum between 0.02 and 0.5 per cent zinc sulphate.

Cyanide gas. Results with cyanide gas, for plants which were not killed by the treatment, are given in figure 2, A. In 2 trials with snapdragon rust, 80 to 100 per cent eradication resulted on 4-day-old infections exposed to calculated doses of 60 to 100 p.p.m. cyanide gas for 12 hr. in large cans. In 3 trials with bean rust in large cans, 0 to 100 per cent eradication of 4-day-old lesions resulted from 12-hour exposures to 60 to 400 p.p.m. In two trials with bean rust in 450-cc. jars, 70 to 100 per cent eradication of 4-day-old lesions resulted from 15-min. exposures to 600 to 2,000 p.p.m. of cyanide. Eradication was generally poorer along the veins of the leaves, presumably because the leaves are thicker there. Usually there was some host injury from cyanide gas, but the greater susceptibility of the rust fungus than the host to cyanide gas was marked in all cases

where the host was not killed, and in a few cases complete rust eradication resulted without apparent host injury.

Volatile gases from lime sulphur and sodium sulphide. With exposure periods of 5 hours, the gases from dilute lime sulphur usually gave com-

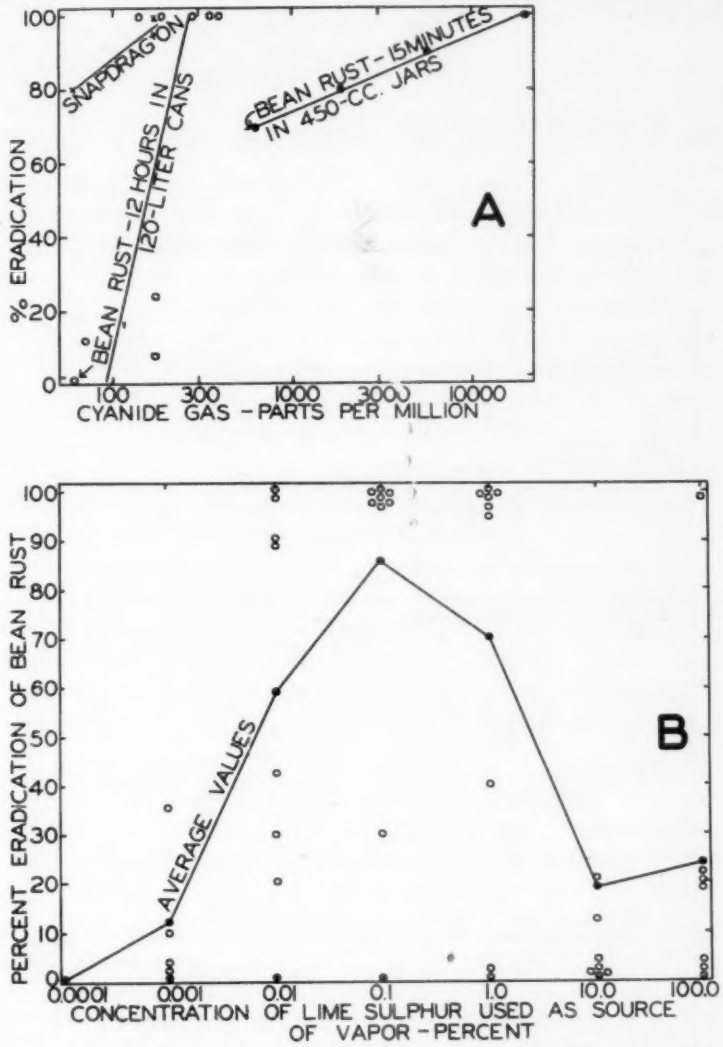
% ERADICATION
SNAPDRAGON
BEAN RUST - 12 HOURS IN 120-LITER CANS
BEAN RUST - 15 MINUTES IN 450-CC. JARS
A
CYANIDE GAS - PARTS PER MILLION
PERCENT ERADICATION OF BEAN RUST
AVERAGE VALUES
B
CONCENTRATION OF LIME SULPHUR USED AS SOURCE OF VAPOR - PERCENT

FIG. 2. A. Eradicant action of cyanide gas for snapdragon rust and bean rust. The tests on snapdragon rust, upper left, were exposures of 12 hours in 120-liter cans. B. Eradicant action on bean rust of the volatile products from various concentrations of lime sulphur.

plete eradication of 3- to 7-day-old bean rust infections without host injury in a large number of trials (Fig. 2, B). For commercial lime sulphur (specific gravity 1.28) diluted with distilled water the most therapeutic concentration was about 0.1 per cent, with less therapy resulting from lower or higher concentrations. The low therapeutic value of vapors from

high concentrations of lime sulphur is associated with their strong alkalinity, since with 0.1 per cent lime sulphur and 0.05 per cent sodium sulphide, the optimum pH (as manipulated with 0.1 N HCl) for therapy

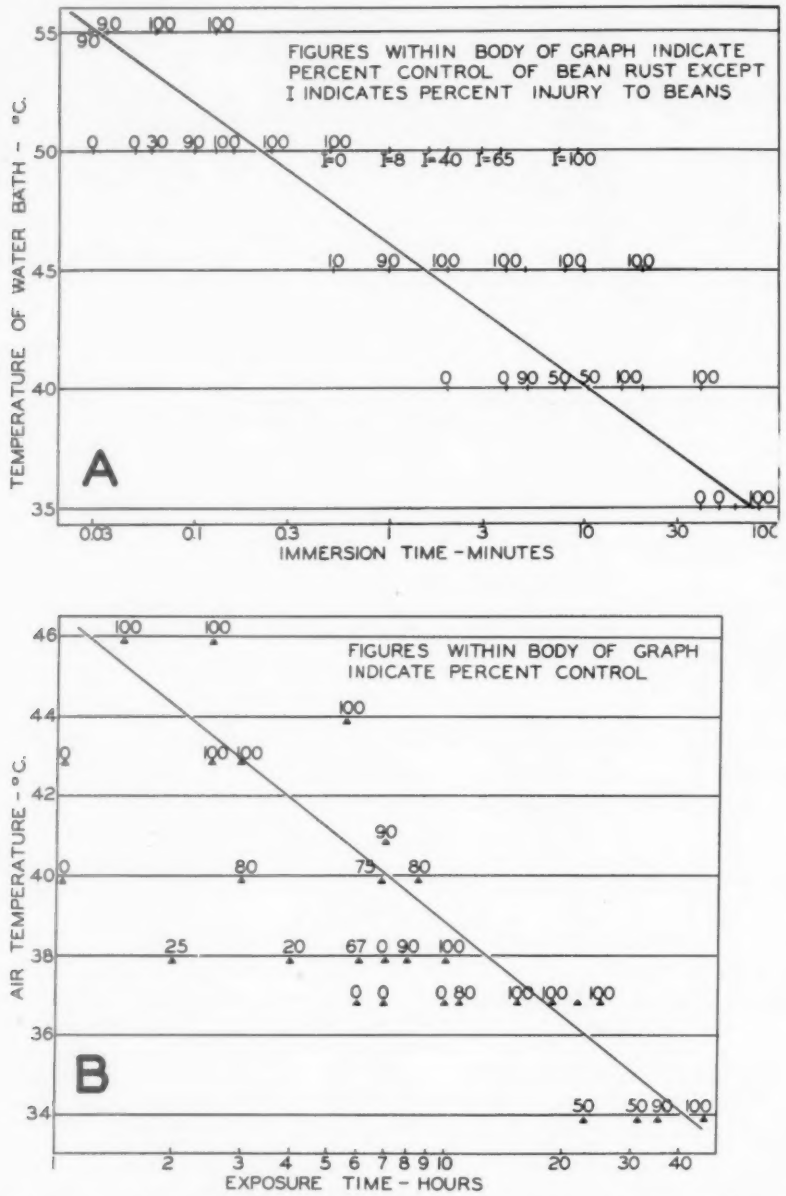
FIGURES WITHIN BODY OF GRAPH INDICATE PERCENT CONTROL OF BEAN RUST EXCEPT I INDICATES PERCENT INJURY TO BEANS
TEMPERATURE OF WATER BATH - °C.
IMMERSION TIME - MINUTES
A
FIGURES WITHIN BODY OF GRAPH INDICATE PERCENT CONTROL
AIR TEMPERATURE - °C.
EXPOSURE TIME - HOURS
B

FIG. 3. A. Eradicant action of hot water for bean rust, and injury to beans from water at 50° C. B. Eradicant action of hot air for snapdragon rust.

without host injury was about pH 9, while the unadjusted pH of all solutions of these or higher concentrations was always above this. As judged

by the darkening of lead acetate paper in the test chambers, there was a correlation between hydrogen sulphide formed and therapeutic activity. However, in other trials with bean powdery mildew (*Erysiphe polygoni*) therapy resulted from a mixture containing 0.1 per cent lime sulphur + 0.1 per cent $KMnO_4$, where H_2S could usually not be detected with lead acetate.

Hot water. Results for bean rust of all therapy tests with hot water from 35° C. to 55° C., in 5°-intervals, are presented in figure 3, A. The results indicate complete eradication of bean rust in 80 min. at 35° C., 15 min. at 40°, 2 min. at 45°, 0.13 min. at 50°, and 0.06 min. at 55°. The best straight line through these points indicates a Q10 (ratio of immersion times for equivalent lethal effect over a range of 10° C.) of about 44 between 35° and 55° C. Uredial pustules killed by hot water made no further growth. If therapy treatments were made at 4 days after inoculation, when the rust pustules were barely apparent, no host injury usually occurred at the therapy dosages indicated, but at 7 and 10 days after inoculation, treatments which killed the rust usually killed the leaf tissue for about a millimeter beyond the pustule. As judged by results of one test with beans at 50° C., there was apparently a wide margin between eradication of the parasite and injury to the host (Fig. 3, A). There was no host injury from 30 sec. at 50° C., which was about 3 times the time necessary for complete eradication. For exposures of 30 sec. to 9 min. at 50° C. there was a progressive increase in host injury from 0 to 100 per cent.

In the one test of hot water therapy for mint rust, treatments of 10-day-old infections gave the following results: 10 min. at 40° C.—30 per cent eradication, 1.5 min. at 45° C.—80 per cent eradication, 12 sec. at 50° C.—100 per cent eradication, and 4 sec. at 55° C.—100 per cent eradication; all with no host injury. From these results it would appear that the relative sensitivity of mint rust and mint plants was probably not greatly different from that of bean rust and bean plants. There was no possibility in these experiments of the cure of mint rust being due to killing of the surface spores, as was the case in Niederhauser's (4) tests. In the successful treatments the killed uredial pustules were sunken, dull in color, and obviously inactive 10 days after treatment, while untreated pustules were raised, brown, and powdery.

Hot air. Satisfactory hot air therapy was secured only with snapdragon rust, and results of these tests, presented in figure 3, B, indicate that snapdragon rust can be eradicated by hot air dosages ranging from 30 min. at 46° C. to 40 hr. at 34° C., with a Q10 between these limits of about 20.

DISCUSSION

Therapy is only one of six basic methods of plant disease control, and is at present the least used. The frequent excursions of plant pathologists into this field of study have yielded relatively little of practical value for

many years, and the present study is no exception. However, the need for curative treatments exists, and undoubtedly practical uses will arise from basic studies of the subject. In the present study the practical value of hot water treatment to control rust infections in planting stock, as with mint rust, is demonstrated, and the possible control of rust diseases in greenhouses, by sulphur vapors, is indicated. The use of sulphur vapor in this way should also prove of value in further basic studies, such as studies of the relative absorption and fixation of sulphur vapors by healthy and fungus infected plant tissues.

The rust fungi studied are obviously more sensitive to the treatments used than are their hosts. With hot water the lethal exposure for bean rust at 50° C. was only about one-sixth that of the lethal exposure for bean leaves. This would indicate that bean rust has evolved under lower maximum temperatures than have beans. Evolutionary significance is less apparent in the results with sulphur and cyanide.

In other reports of heat therapy, specific times at a specified temperature are usually indicated. This study would indicate there is no optimum temperature, and that a great range of temperatures could be used (in the case of bean rust, from 35° to 55° C.) provided appropriate exposure times were chosen.

SUMMARY

Bean and sunflower plants inoculated with uredospores of their respective rusts, placed in a moist chamber, and returned to a dry atmosphere at varying times after inoculation, showed no subsequent infection when the plants were dried 2 hr. after inoculation, but increasing infection with incubation periods up to about 18 hr. before drying. When infected plants were sprayed with surface applications of 2 per cent rosin lime sulphur or 0.1 per cent copper sulphate plus spreader, subsequent infection was inversely proportional to the interval between inoculation and spraying for periods between 18 and 90 hr. after inoculation. Penetrating applications of dilute lime sulphur were effective in eradicating bean rust up to 8 days after inoculation with little host injury, and the effectiveness of these penetrating spray applications was increased with increasing lime sulphur concentrations, with the addition of a spreader or zinc sulphate to the lime sulphur spray, and with enclosure in a moist chamber following spraying.

Cyanide gas at concentrations ranging from 70 to 2,000 p.p.m. was effective in eradicating bean and snapdragon rust in exposures of 15 min. and 12 hr., but host injury usually resulted. The vapors from lime sulphur solutions ranging from 0.001 per cent to 100 per cent lime sulphur eradicated bean rust from 4- and 7-day-old infections, with the maximum therapy from 0.1 per cent lime sulphur. The optimum alkalinity for the volatile therapeutic action of 0.1 per cent lime sulphur or 0.05 per cent Na_2S was about pH 9.

Four- to 10-day-old infections of bean rust and 10-day-old infections of mint rust were killed without marked host injury when infected leaves were immersed in water at 35° to 55° C. for intervals varying from about 80 min. to 4 sec., respectively, with a temperature coefficient of about 44. Snapdragon rust was similarly eradicated with dry air at 34° to 46° C. in 40 hr. to 30 min., respectively, with a temperature coefficient of about 20.

DIVISION OF PLANT PATHOLOGY,
UNIVERSITY OF CALIFORNIA,
BERKELEY, CALIFORNIA.

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RESULTS OF ELEVEN YEARS' SPRAYING FOR PECAN SCAB CONTROL WITH HIGH-LIME AND LOW-LIME BORDEAUX MIXTURE

JOHN R. COLE[1]

(Accepted for publication March 2, 1948)

INTRODUCTION

Pecan scab, caused by *Cladosporium effusum* (Wint.) Demaree, is one of the most important limiting factors in nut production, especially in areas of high rainfall and humidity, and its control is of vital importance to the pecan industry. All widely planted commercial varieties, other than the Stuart, are susceptible to scab in some localities and may require spraying to control the scab disease. The Stuart is the most widely planted of all varieties throughout the pecan-growing area.

Demaree and Cole (6) found that strains of the scab fungus show selective parasitism for certain varieties, and for that reason "trees of susceptible varieties might be growing in the same orchard in contiguous rows, or even with their branches interlocking those of scab diseased trees of another variety and not be affected with the disease. Varieties are sometimes very susceptible in one locality and apparently immune in another."

Observations by the writer indicate that the build-up and increase of virulent strains of the fungus from susceptible varieties to those previously resistant is a gradual process and usually takes place over a period of several years.

EXPERIMENTS TO CONTROL PECAN SCAB

Early investigators, Waite (13), Spooner (12), McMurran and Demaree (8), Neal (9), Demaree and Cole (4, 5), Nolen (10), and Boyd (2), did considerable experimental work on the control of pecan scab using the standard spray and dust materials, i.e., high-lime Bordeaux mixture, lime-sulfur solutions, and copper-lime dusts. In addition, the recommended schedules stipulated that the first application be postponed until after the nuts had been pollinated. Most spraying recommendations included the use of two spray guns for each tree—one to spray lower and one upper portions of the tree simultaneously. When the trees were sprayed according to these recommendations there was usually an accumulation of Bordeaux mixture on the leaves, therefore spray or drought injury occurred in most orchards during late summer and early fall, especially during seasons when the daily distribution of rainfall was less than normal. Certain growers considered spraying so hazardous that it was practically abandoned.

[1] Pathologist, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, Albany, Georgia.

No injury from fungicides applied as dusts was noticeable but commercial control was not obtained, therefore dusting was likewise abandoned.

Baker and Cole (1) sprayed pecan trees with 4–6–100 Bordeaux mixture before the pistillate flowers were pollinated and no injury to the flowers or foliage occurred, provided the temperature was above 55° F. It had earlier been considered hazardous by most research workers to spray in the prepollination stage because of the injury that might result.

Demaree and Large (7) reported moderate spray or drought injury to Schley pecan trees following 4 applications of 4–5–100 Bordeaux and severe injury when 4 applications of 6–8–100 and 6–16–100 Bordeaux were used. The extent of the injury depended upon the distribution of rainfall as well as the variety of pecans sprayed. The Schley variety was highly susceptible to drought or spray injury. All spray applications were made after the pistillate flowers had passed the receptive stages, and two spray guns were used.

Wilson and Runnels (14) report that Ginseng was severely injured when sprayed with 3 applications of 6–9–100 Bordeaux mixture in Ohio during the summer of 1930, while the seasonal distribution of rainfall was less than normal. In the final stages of this injury the sprayed plants collapsed and died, as if suffering for want of moisture. The writers did not describe the type of spray equipment used to apply this spray. Neither did they state the dosage of Bordeaux mixture applied.

In 1935 Cole and Large (3), while testing various fungicides, successfully controlled scab on the very susceptible Schley variety by using only one spray gun and making one prepollination application of 4–1–100 Bordeaux mixture, followed by 3 applications of 6–2–100 Bordeaux mixture. No visible injury resulted to the leaves or nuts.

Following the preliminary successes obtained in 1935, 36 Schley trees were randomized in single tree plots of 9 trees each to accommodate 4 treatments. The trees were given 3 applications of one of the following sprays in 1936: 6–2–100 Bordeaux mixture, 6–2–100 Bordeaux plus 1 quart summer oil emulsion, or 6–6–100 Bordeaux. Checks were not sprayed. These treatments followed one prepollination spray application of 4–1–100 Bordeaux mixture used uniformly on all sprayed plots. The various Bordeaux mixtures were compared in relation to drought or spray injury on pecan foliage. These plots were sprayed according to this schedule each succeeding year for eleven years.

Only one spray gun was used to apply the material and the operator always stood on top of the spraying machine. Each tree was circled in applying the spray and the machine was never stopped. The sprayer used had a pump capacity of 35 gal. per min. and was operated by its own power. The trees were 30 years old when the test was begun and the average amount of material used was 25 gal. per application and approximately 100 gal. per season.

Table 1 contains a summary of the yield of nuts in pounds and the number of orchard-run, cured nuts required to weigh a pound.[2]

The yield from trees sprayed with the high-lime (6–6–100) formula did not differ significantly from the yields from trees sprayed with the low-lime (6–2–100) formula.

All yields from sprayed trees were highly significantly greater than the yields from the unsprayed check trees.

The differences in the number of nuts per pound between the three spray treatments were not significant. However, the difference in weight

TABLE 1.—*The 11-year mean yields of Schley[a] pecan nuts in pounds per tree, and the number of nuts per pound, as influenced by the application of various Bordeaux mixtures*

Treatment	No. of trees per treatment	Mean yield, lb. per tree	Mean No. nuts per lb.
1 application of 4–1–100 Bordeaux mixture followed by 3 applications of 6–2–100 Bordeaux mixture	9	50	73
1 application of 4–1–100 Bordeaux mixture followed by 3 applications of 6–2–100 Bordeaux mixture plus summer oil emulsion, 1 qt.–100	9	45	70
1 application of 4–1–100 Bordeaux mixture followed by 3 applications of 6–6–100 Bordeaux mixture	9	42	72
Check, no spray	9	18	107
Difference required for significance at 5 per cent level		9	19
Difference required for significance at 1 per cent level		13	25

[a] Schley variety, ten trees per acre.

of the nuts from sprayed trees and from the check trees was significant at the one per cent level.

At no time during the course of this experiment was there any evidence of spray or drought injury to the trees in any of the treatments used in the test. Apparently the injury formerly reported as "spray" or "drought" injury was due to the method of application of the material which resulted in over-spraying and was not due to the Bordeaux mixture used.

The trees in the plots sprayed with 6–2–100 Bordeaux gave slightly higher yields of nuts than those in either the 6–2–100 Bordeaux plus summer oil emulsion or the 6–6–100 plots. Since the first formula is more economical than the other mixtures, the 6–2–100 Bordeaux mixture is recommended for pecan scab control.

SUMMARY

Results are given of spraying tests for eleven years with 6–2–100 Bor-

[2] Acknowledgment is made to J. H. Hunter, Soil Technologist, U. S. Department of Agriculture, Pecan Laboratory, Albany, Georgia, for his assistance in computing the statistical data contained in the table.

deaux mixture, a 6–2–100 Bordeaux plus summer oil emulsion, and a 6–6–100 Bordeaux to control pecan scab, only one spray gun being used so as to avoid over-spraying.

There was no significant difference in yield of nuts resulting from the various Bordeaux mixtures used. The differences in yield between the sprayed and the unsprayed trees were highly significant.

Since there was no visible sign of spray or drought injury on any of the sprayed trees used in this test, the writer believes the spray injury reported by former workers may be attributed to the method of application rather than to the materials used.

Because a 6–2–100 Bordeaux mixture is more economical and produces slightly higher yields of nuts than either a 6–2–100 Bordeaux plus oil emulsion or a 6–6–100 Bordeaux mixture, it is recommended for pecan scab control.

U. S. DEPARTMENT OF AGRICULTURE,
PECAN FIELD LABORATORY,
ALBANY, GEORGIA.

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ERGOT AND STERILITY IN BAHIA GRASS[1]

GLENN W. BURTON AND C. L. LEFEBVRE[2]

(Accepted for publication March 10, 1948)

Ergot (*Claviceps paspali* Stevens and Hall) was observed on Bahia grass (*Paspalum notatum* Flugge) at Tifton, Georgia, for the first time in 1938 and has occurred in considerable abundance every year since. During these years most of the infected florets have been filled with ergot sclerotia and covered with sticky "honey-dew" exudate. Only a very few florets, however, have been found with sclerotia large enough to pry the lemma and palea apart and extend beyond them.

The direct association between ergot and sterility in Bahia grass was first observed in five Paraguay × common Bahia hybrids in 1941. These hybrids were highly sterile as indicated by their poor seed setting performance but were more heavily infected with ergot than either parent.

Other hybrids produced later gave rise to uniform progenies exactly like the female F_1 parent, indicating that they were reproducing by apomixis.[3] An analyses of seed samples taken from each plant within 40 plant progenies of these hybrids revealed that the hybrids differed significantly in the percentage of florets producing sclerotia.[3] A correlation coefficient of -0.86 was obtained between the average percentage of florets setting seed and the average percentage of florets producing sclerotia for these hybrid progenies, indicating that the percentage of sclerotia increased as the fertility of the hybrid progeny decreased. Since each of the hybrid progenies supplying the mean values for the correlation were different in appearance, they might have differed in ergot resistance, sterility, or both. Hence, it was impossible to ascertain whether the greater susceptibility to ergot prevented seed setting or the greater sterility allowed more sclerotia to be formed.

In 1941, a single male sterile plant was found growing in a progeny of 192 white stigma common Bahia plants. This individual differed from the other 191 plants only in its male sterility. Since the progeny was believed to have arisen by apomixis and the male sterile plant to have originated by mutation, it seemed highly probable that the gene complex of the male sterile was identical with that of the other 191 plants except for the gene or genes causing male sterility. The failure of F_1 hybrids between the male sterile and fertile plants to segregate made it impossible to ascertain the number of genes responsible for the male sterile mutant.[3]

The male sterile Bahia plant set no seed except when pollinated and

[1] Cooperative investigations at Tifton, Georgia, of the Division of Forage Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, the Georgia Coastal Plain Experiment Station, and the Georgia Experiment Station.

[2] Senior Geneticist and Pathologist, U. S. Department of Agriculture.

[3] Burton, Glenn W. Studies of the method of reproduction in common Bahia grass, *Paspalum notatum*. Jour. Amer. Soc. Agron. (in the press).

then produced seed giving rise to many apomictic plants like itself. When unpollinated heads of this clone were inoculated with ergot "honey dew" by smearing "honey dew" droplets on the florets, they became infected and produced as much "honey dew" as fertilized heads of its sister plants. This observation indicated that ergot development is not dependent upon the fertilization of the Bahia grass floret.

In 1942, twenty-seven male sterile plants and a similar number of fertile sister plants were spaced 3 feet apart so that a male sterile and a male fertile plant occurred together in pairs. Seed harvested from each of

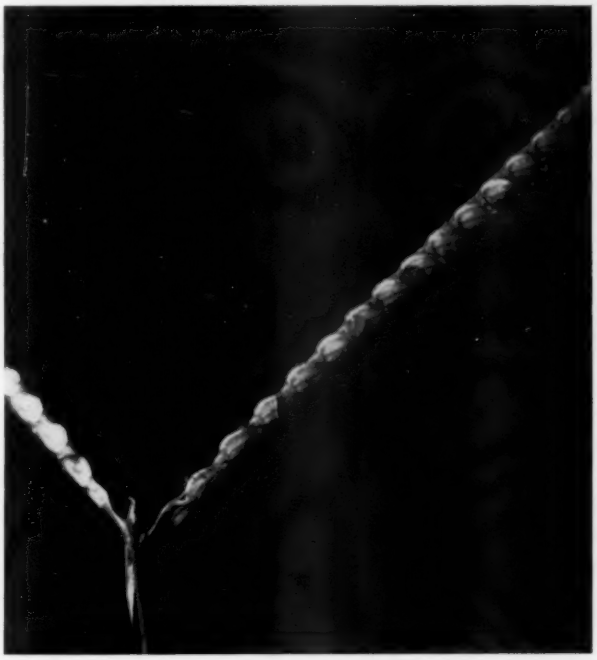

FIG. 1. Ergot "honey-dew" exuding from Bahia grass florets 8 days after artificial inoculation.

these plants were analyzed for the percentage of florets containing caryopses and the percentage of florets containing sclerotia. A summary of the results showed that the proportions of florets to set seed was 35.7 per cent for the male fertile plants and 6.2 per cent for the male sterile plants. Only 9.6 per cent of the male fertile florets contained sclerotia while 33.1 per cent of the male sterile florets contained sclerotia. These differences between the male fertile progenies exceeded the 1 per cent level of significance for both measurements. Since the male sterile and male fertile plants should have been genetically the same except for the male sterility factor, the differences in the amount of ergot produced by each must have been due to their differences in male sterility. This observation suggests that care must be exercised in an ergot resistance breeding program lest

differences in ergot readings due to sterility differences be mistaken for genetic differences.

An explanation for the observed relationship between ergot and sterility in Bahia grass can only be suggested at this time. The stigmas of the self fertile common Bahia grass usually begin to dry up within 24 hours after pollination if fertilization has occurred. When not pollinated, these stigmas remain fresh for many days. Consequently, the relative abundance of fresh stigmas on Bahia grass panicles furnishes a good index of the degree of fertilization and the seed set that may be expected later. The male sterile Bahia, for example, always shows a much higher proportion of fresh stigmas than the male fertile Bahia. These observations suggested that delayed pollination might be causing the greater incidence of ergot in the male sterile Bahia grass.

To test the theory a number of male sterile and male fertile florets were brought into the laboratory on September 20, 1947. Florets on a number of panicles blooming the first day were painted white and those opening on the second day were painted pink. All florets not blooming by the third day were removed. All florets were heavily pollinated each day. Approximately 30 minutes after pollination on the third day all panicles were immersed in a water suspension of ergot "honey dew." Several unpollinated panicles of the male sterile Bahia were inoculated at the same time to check the efficacy of the technique. Eight days later "honey dew" was observed exuding from many of the florets on the inoculated unpollinated male sterile panicles. See figure 1. Only three sclerotia were found in more than 200 florets that were pollinated 30 minutes before inoculation. No sclerotia were found in the florets pollinated 24 and 48 hours before inoculation. These observations suggest that pollination soon rendered the florets impregnable to the attack of ergot.

DISCUSSION

The observations reported here would seem to justify the following working hypothesis, which may be used to guide future investigations. Ergot apparently is capable of attacking and growing upon susceptible Bahia grass florets that are sterile because of cytological abnormalities or lack of effective pollination. Pollination and fertilization seem to set up a mechanism which soon renders the susceptible floret resistant to later attack by ergot. Consequently, only those florets inoculated with ergot before or soon after effective pollination may become ergotized.

SUMMARY

1. Highly sterile Paraguay × common Bahia grass hybrids were much more heavily ergotized than either parent.

2. A correlation coefficient of -0.86 was obtained between percentage seed set and ergot abundance in Bahia hybrid progenies varying significantly in fertility.

3. An apomictic progeny of a male sterile mutant produced over 5 times as many ergotized florets as a similar progeny of a male fertile sister plant compared with it.

4. Pollination and fertilization were shown to be unnecessary for the development of ergot in Bahia grass.

5. Susceptible Bahia grass florets inoculated and not pollinated produced many ergot sclerotia. Inoculating 30 minutes after pollination resulted in the production of a few sclerotia. Florets inoculated 24 and 48 hours after effective pollination developed no sclerotia. Effective pollination resulting in fertilization and seed set seems to soon render the florets of Bahia grass resistant to ergot attack.

U. S. DEPARTMENT OF AGRICULTURE,
GEORGIA AGRICULTURE EXPERIMENT STATION,
AND
GEORGIA COASTAL PLAIN EXPERIMENT STATION.

A NEW FUSARIUM DISEASE OF LANG (LATHYRUS SATIVUS)[1]

VISHNU P. BHIDE[2] AND B. N. UPPAL[3]

(Accepted for publication March 15, 1948)

A destructive, new wilt disease of lang (*Lathyrus sativus* L.) appeared in the Broach district of Bombay Province, India, in 1935–36 and assumed serious proportions in subsequent years. Since a disease of this type had never been reported before, a study of it was undertaken with a view to describing its symptoms and determining the cause. The results of a part of the investigation are reported here.

SYMPTOMS OF THE DISEASE

Lang is an important cold weather crop in the Broach district of Bombay Province where 100,000 acres are grown annually. It is regularly cultivated in rotation with jowar (*Sorghum vulgare* L.) and cotton. It is an annual and is much prized for its green fodder; its grain is fed to cattle in times of scarcity besides its use as a pulse by the poorer classes. Losses from wilt are generally 10 to 15 per cent, though fields showing 60 to 70 per cent infection are not uncommon in some years.

The disease generally appears in late December when the plants are in full bloom. Patches of wilted plants appear at this time and these enlarge in all directions as the season advances.

Yellowing of leaves is the first noticeable symptom of wilt in the field; it starts with the oldest leaves and proceeds upwards until the whole plant is involved. Yellowed leaves become flaccid, droop, and eventually dry. Sterility of affected plants is very common, and if a few pods are already formed before a plant becomes infected, they never mature and contain only a few, shrunken seeds. Discoloration of the vascular system, characteristic of Fusarium wilts, is found only in the root system. Partial wilting is also a common symptom. When once infected, plants slowly dry up and die.

In pot-culture in the greenhouse, drooping of leaves is the only symptom of wilt in young plants, which die very suddenly. Yellowing of leaves is sometimes seen when older plants are infected. Vascular discoloration of the root system is present in such plants, whereas young infected plants seldom show it.

PATHOGENICITY

The fungus was very easily isolated from roots of infected plants by the usual method of planting infected tissue on potato-dextrose agar. Numerous isolations were made from wilted plants collected from various localities in the Broach district. In the majority of cases, the isolations yielded a species of *Fusarium* which did not produce any pigment or fructification

[1] Taken from a thesis submitted by the senior author to the University of Bombay for the Ph.D. degree in Agriculture.

[2] Lecturer in Plant Pathology and Bacteriology, College of Agriculture, Poona, India.
[3] Plant Pathologist to Government, Bombay Province, India.

on potato-dextrose agar, but showed an abundance of single, ovoid microconidia and smooth, single, terminal or intercalary chlamydospores. No macroconidia were produced on this medium.

The pathogenicity of the fungus was determined by growing plants in steamed river bottom soil that had been infested with a pure culture from Richards' solution. The infested soil was held in a closed metal bin for four weeks and then placed in clay pots disinfested in 5 per cent copper sulphate solution. Four seeds were sown in each of twelve pots and held in the greenhouse at 23° to 28° C. A comparable number of cultures employing steamed, non-infested soil were held in the same greenhouse as a check.

Wilt appeared when seedlings were 12 days old, and progressed rapidly until about 70 per cent of the plants had wilted in a month. No disease appeared in the checks. Isolations from wilted plants yielded a typical *Fusarium* which was identical with the original culture that had been placed in the soil.

RELATION OF TEMPERATURE TO THE GROWTH OF THE FUNGUS

The temperature-growth relations of the fungus were studied on Richards' agar. Plates of this medium were inoculated with a young culture of the fungus and incubated at various temperatures. A spore suspension of the fungus was used to inoculate the plates with a standard loop. Triplicate plates were carried at each temperature and growth was measured as mean colony diameter at the end of six days' incubation. Table 1 shows the results.

TABLE 1.—*Mean colony diameter after six days' growth on Richards' agar at different temperatures*

Temperature	Mean colony diameter	Temperature	Mean colony diameter
°C.	cm.	°C.	cm.
0.0	0.0	24.5	4.3
7.2	0.0	27.0	5.0
11.1	0.5	29.0	4.8
15.5	1.3	31.0	3.8
20.0	2.0	33.0	0.6
22.0	4.0	35.0	0.0

The fungus has a wide growth-temperature range; the optimum is about 27° C., and the minimum and maximum about 11° and 33° C., respectively.

RELATION OF SOIL TEMPERATURE TO WILT

It is well known that soil temperature is a limiting factor for the development of Fusarium wilts. The effect of soil temperature on wilt in lang was determined by growing it in Fusarium-infested soil maintained at various soil temperatures in Wisconsin soil temperature tanks.

In the first trial, four tanks were set up to maintain soil temperatures of 20°, 25°, 30°, and 35° C. The daily fluctuations in every case were not more

than ± 0.5° C. Each tank held six cans of infested soil and one of steamed soil as a check. Twenty seeds of lang, previously disinfected in a 1:1,000 solution of mercuric chloride were then sown in each can. Temperatures, both soil and air, were recorded three times a day.

Wilt appeared at 25° C. when the seedlings were seven days old and at 20° and 30° when they were 10 days old. The appearance of the disease was delayed at 35° C. until the plants were 22 days old. Records of deaths were taken every three days, and the test was stopped when no more plants wilted. Each surviving plant was then carefully uprooted and its roots were examined for vascular discoloration. Those plants with vascular necrosis of the roots were classed as infected and the rest as healthy.

In another trial, five soil temperature tanks were set up to maintain soil temperatures of 27°, 30°, 32°, 35°, and 37° C., respectively. Wilt appeared when the seedlings were seven days old at 27° C. and when they were 12 days old at 30° and 32° C., whereas at 37° C. germination was very poor

TABLE 2.—*Percentage of plants with infection at different soil temperatures*

Mean soil temperature (°C.)	No. of plants	Percentage of wilting observed			Vascular necrosis (Per cent)
		After 10 days	After 20 days	After 32 days	
19.9	91	0.0	48.5	69.0	94.0
25.0	87	2.0	59.0	81.0	100.0
29.9	82	0.0	13.0	60.0	90.0
34.8	85	0.0	0.0	9.0	52.0
27.0	158	2.0	25.3	75.5	85.4
29.9	89	0.0	12.3	54.6	66.9
32.5	73	0.0	9.3	12.5	12.5
34.8	84	0.0	0.0	6.0	16.0
37.0	37	0.0	0.0	0.0	0.0

and the resulting plants remained stunted and unhealthy. No wilt appeared at this temperature. The survivals were examined as before for root discoloration. The results of these trials are given in table 2.

The results show that wilt reaches its maximum development at soil temperatures between 25° and 27° C., at which level it is characterized by the earliness of attack and the severity of infection. At lower and higher levels, the incubation period increases and the severity decreases. These observations, taken together with the temperature-growth relations of the fungus indicate that a positive correlation exists between the growth of the fungus and disease development at various soil temperatures.

These results are similar to those obtained by Gilman (3), Tims (7), and Tisdale (8) for *Fusarium conglutinans* on cabbage, Clayton (1) for *Fusarium lycopersici*, causing wilt of tomatoes, and Uppal and Kulkarni (9) for *Fusarium vasinfectum* on *Crotolaria juncea*.

HOST RANGE

Plants of several species were grown in soil infested with *Fusarium* from lang to see whether they were susceptible to this parasite. About 50 seeds

of each of the following were sown in infested soil held at 25° C. in soil temperature tanks (the optimum for disease incidence in lang): sweet peas (*Lathyrus odoratus*), everlasting peas (*Lathyrus latifolius*), cabbage (*Brassica oleracea*), celery (*Apium graveolens*), beet (*Beta vulgaris*), garden peas (*Pisum sativum*), field peas (*Pisum sativum* var. *arvense*), gram (*Cicer arietinum*), and cotton (*Gossypium herbaceum*). Lang was sown as check.

After one month, about 80 per cent of the lang was dead but all plants of the other species remained healthy. At the end of two months, every plant was uprooted and the roots were examined for discoloration, which was absent in all cases except lang. These results indicate that the fungus is restricted in its parasitism to its own host, as far as the species tested are concerned.

MORPHOLOGY AND CULTURAL CHARACTERS OF THE FUNGUS

Growth on various media. The fungus was grown on a number of media in order to obtain a complete range of spore forms as recommended by Wollenweber et al. (10). Synthetic agar, potato hard agar, and Richards' agar were also used as done by Doidge (2). The cultures were grown at room temperature (24° – 27° C.) in darkness and observations were made regularly. Ridgway's (5) color nomenclature was used to describe the colors produced by the fungus.

No sporodochia, pionnotes, or sclerotia were produced on any media. Microconidia and chlamydospores were produced on all media whereas pigment was evident only on a few media. The results are summarized in table 3.

TABLE 3.—*Growth characteristics of the fungus on different media*

Medium	Mycelium (aerial)	Pigment		Macroconidia
		Mycelium	Substrate	
Green bean pod	moderate	pale yellow green	none	few
Banana peel	sparse	pale yellow orange	none	few
Steamed rice	moderate	white	faint violet	none
Potato hard agar	moderate	white	none	none
Synthetic agar	profuse	white	pale orange	none
Richards' agar	profuse	white	pale orange yellow	none
Oatmeal agar	thin	white	cinnamon-brown	none
Potato-dextrose agar (2 per cent)	moderate	white	none	none
Potato-dextrose agar (5 per cent)	none	none	none	none

Measurements of conidia and chlamydospores.

Conidia: from three-weeks-old culture on bean pod.
0-septate, 70.5 per cent, 7.4 (3.4–10.6) × 3.4 (2.5–5.0) microns.
1-septate, 20.0 per cent, 15.8 (12.5–17.5) × 4.4 (3.8–5.0) microns.
2-septate, 4.0 per cent, 21.6 (18.8–25.0) × 3.8 (3.0–5.0) microns.
3-septate, 5.5 per cent, 24.3 (17.5–32.5) × 3.3 (3.0–3.7) microns.
Conidia: from three-weeks-old culture on banana peel.
0-septate, 92.0 per cent, (not measured).
1-septate, 4.0 per cent, (not measured).
2-septate, rare, (not measured).
3-septate, 4.0 per cent, 30.3 (25.0–42.5) × 4.3 (3.8–5.0) microns.
Chlamydospores: from one-month-old culture on 2 per cent potato-dextrose agar.
9.9 (7.9–15.4) microns in diameter.

Microconidia are single, hyaline, ovoid or ellipsoid. Macroconidia are straight or slightly curved, non-pedicellate, hyaline, and with delicate walls and septation. Chlamydospores are single, terminal as well as intercalary, produced by the mycelium, rarely in conidia, spherical, smooth, and rich in contents. Conidiophores simple. Sclerotia absent.

IDENTITY OF THE PATHOGEN

The presence of terminal and intercalary chlamydospores, delicate walls and septation of the macroconidia, and the abundance of single, one celled, ovoid microconidia place the *Fusarium* in the section Elegans; within this section, the total absence of sporodochia immediately identifies the fungus with the sub-section Orthocera. For a species diagnosis of the fungus, the characters of value are the absence of pionnotes, non-erumpent stroma, simple conidiophores, color on steamed rice, and the size of 3-septate conidia. These characters align the fungus with *Fusarium conglutinans* Wr. which it closely resembles except that it is non-pathogenic to cabbage and produces a faint violet color on steamed rice.

If color production is considered a major criterion for diagnosis of species in this sub-section, the fungus then resembles *F. orthoceras* App. and Wr. The pigment produced is not, however, as intense as that of *F. orthoceras*.

Padwick (4) made a detailed study of 11 of the 12 Orthocera-Fusaria using authentic cultures and came to the conclusion that there was no basic difference in the two species, *Fusarium conglutinans* and *F. orthoceras*. These two differ mainly in color production and size of conidia besides pathogenicity, but Padwick (4) showed that these two characters are extremely variable. In his experiments, *F. conglutinans* and all its varieties were non-pigmented whereas *F. orthoceras* and its varieties could be classified into three groups based on color production. A purple color was produced by *F. orthoceras* and its varieties *apii* and *longius*, a blue color was produced by *F. orthoceras* var. *pisi*, and no pigment was produced by *F. orthoceras* var. *apii* f. 1. Moreover, the colors produced were not necessarily the same as those described by Wollenweber and Reinking (11).

As regards spore size, the non-septate conidia of any of the species showed variations which were as great as or greater than those between species. As most of the species did not produce any macroconidia, variations in this character could not be measured.

Snyder and Hansen (6) in 1940 formally recommended the merging of all the species, varieties, and forms of Elegans-Fusaria (41 in all) into one single species, *Fusarium oxysporum* Schlect. In order to achieve this, they emended the description of *F. oxysporum*. The various parasitic members of the section Elegans became biologic forms of the master species, and the saprophytic forms were merged with it. They presented experimental evidence to show that the characters that go to differentiate between the subgroups of the section Elegans (presence or absence of sporodochia and the size of spores) are not stable and hence the absence of justification for maintaining them. The authors believe that there is no need for such a drastic step since it normally is possible to place an Elegans Fusarium in its proper sub-group following the key of Wollenweber and Reinking (11). Moreover, since pathogenicity remains a criterion for delimitation of pathogenic forms, the proposed change does not improve things a great deal.

In the present work, the variations in the size of 3-septate conidia is very striking. On bean pod the spores measure 24.3 (17.5–32.5) × 3.3 (3.0–3.7) μ, whereas on banana peel the measurements are 30.3 (25.0–42.5) × 4.3 (3.8–5.0) μ. In the key of Wollenweber and Reinking (11) for the Orthocera-Fusaria, the average measurements of 3-septate conidia for *Fusarium conglutinans* and *F. orthoceras* are 34 × 3.5 μ and 33 × 3.5 μ respectively, a difference that is not significant. The only difference in the two species seems to be the absence of color in *F. conglutinans*, and yet a variety of *F. orthoceras* is non-pigmented. The authors agree with Padwick in his decision to unite the two species as there is no real difference between them. It is therefore proposed to describe the lang pathogen as a new variety of *F. orthoceras* with the varietal name *lathyri* on account of its pathogenicity to *Lathyrus sativus*. A technical description of the fungus follows:

Fusarium orthoceras App. and Wr. var. **lathyri** n. var.

Stroma pale, colorless on most media, cinnamon-brown on oatmeal agar, faint violet on steamed rice, non-erumpent. Aerial mycelium colorless, sometimes sending out ochraceous strands. Sporodochia, pionnotes, and sclerotia absent. Microconidia scattered freely in the mycelium, single, ovoid to ellipsoid, measuring on an average 7.4 (3.4–10.6) × 3.4 (2.5–5.0) microns and constitute about 90 per cent of the conidia produced. Macroconidia rarely produced, mostly 3-septate, straight or slightly curved, with delicate walls and septation, non-pedicellate, and measure on an average 27.3 (17.5–42.5) × 4.0 (3.0–5.0) microns. Conidiophores simple. Chlamydospores numerous, terminal and intercalary, single, smooth, spherical, measuring on an average 9.9 (7.9–15.4) microns in diameter.

This fungus causes a vascular wilt of *Lathyrus sativus* L. in the Broach district of Bombay Province, India.

Stromate pallido; sporodochiis, pionnote et sclerotiis deficientibus; microconidiis numerosis, instratis, continuis, ovoideis, 7.4 × 3.4 (3.4–10.6 × 2.5–5.0) μ numerosis; macroconidiis raris, 3-septatis orthoceris vel leniter falcatis, non-pedicellatis, 27.3 × 4.0 (17.5–42.5 × 3.0–5.0) μ; chlamydosporis numerosis, terminalibus et intercalaribus, singulis, globosis, 9.9 (7.9–15.4) μ diam.

Habitat: In disco trunci *Lathyri sativi* L. Bombay, India.

SUMMARY

Wilt in lang (*Lathyrus sativus* L.) is a destructive disease in the Broach district of Bombay Province, India. A new *Fusarium*, isolated from wilted plants, proved pathogenic to lang grown in soil infested with pure cultures of the fungus.

Yellowing of leaves is the first noticeable symptom of wilt in the field. Sterility of affected plants is also common. Discoloration of the vascular system is found in the roots only.

The fungus has a very wide growth-temperature range of 11°–33° C., the optimum being about 27° C.

The pathogen is most destructive at soil temperatures between 25° and 27° C. At lower and higher levels, the incubation period lengthens and the severity decreases.

In experiments on host range, no infection was obtained on sweet peas, everlasting peas, garden peas, field peas, cabbage, celery, beets, gram (*Cicer arietinum*), and cotton (*Gossypium herbaceum*).

The fungus compares favorably with *Fusarium conglutinans* Wr. but differs from it in the presence of color and its inability to infect cabbage. The fungus is made a new variety of *F. orthoceras* App. and Wr. because of its pigmented character and the varietal name *lathyri* is proposed for it on account of its pathogenicity to *Lathyrus sativus*.

A technical description of the fungus is given.

ACKNOWLEDGMENTS

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UNIVERSITY OF BOMBAY, INDIA,

AND

IOWA STATE COLLEGE, AMES, IOWA.

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REPORT OF THE 1948 ANNUAL MEETING OF THE SOUTHERN DIVISION, THE AMERICAN PHYTOPATHOLOGICAL SOCIETY

The 1948 Annual Meeting of the Southern Division of The American Phytopathological Society was held in part as a section at the meeting of the Association of Southern Agricultural Workers February 12, 13, 14, in Washington, D. C. A joint session was held on February 12 with the Potomac Division at Beltsville, Md. About sixty Southern plant pathologists were present and over twenty formal papers were presented.

A business session was held on the morning of February 13, when the following officers were elected:

President, I. L. FORBES
Vice-President, L. M. BLANK
Secretary-Treasurer, J. L. LYLE

Titles and abstracts of papers presented follow.

I. L. FORBES, *Secretary-Treasurer*

Varietal Reaction of Oats to Helminthosporium victoriae. ATKINS, J. G. and E. R. STAMPER. Helminthosporium or Victoria blight of oats was first identified in Louisiana on oats grown from introduced seed in the spring of 1947 and caused severe losses in the 1947 crop. Several of the varieties grown in Louisiana have been tested for varietal resistance in field and greenhouse. Artificially infested seed were used in the field test while a suspension of inoculum was sprinkled over seed planted in infested soil in the greenhouse tests. The percentage of seedlings showing the disease was used in evaluating resistance. In the field test Clinton and Nortex were highly resistant; Fulghum, La. 42–48, Ferguson 922, Alber, Appler, and Camellia were resistant; and Traveler, Letoria, Quincy Red, and Victorgrain were highly susceptible. On the basis of greenhouse tests the same general trends were obtained as in the field test. In addition, Benton, Hastings 100 bushel, Nortex 107, and a number of Coker's Hybrids were highly resistant; Lee Rustler, Ranger, and Louisiana Red Rustproof were resistant; and DeSota, Fultex, Lega, Stanton, Vicland, and Fulgrain were susceptible. Seed treatments have not given favorable results; some of the mercurials have drastically reduced stands when used in excess. Preliminary studies indicate that the fungus is found more frequently on or within the glumes than on the seed itself.

Control of Sweet Potato Scurf by Vine Cuttings. COOK, HAROLD T. Badly scurfed sweet potatoes were treated with borax and bedded in sand. The sprouts were pulled from half of the bed and vine cuttings (sprouts cut approximately 1 inch above the sand) were taken from the other half. Five two-row (285 ft. long) replications of sprouts and cuttings were alternated in a field that had been in sweet potatoes as recently as 1945. Data were taken at harvest time. Yield of primes per row: sprouts, 187 lb.; cuttings, 234 lb. Percentage of scurf free primes: sprouts, 78; cuttings, 97. Scurf severity index: sprouts, 36.7; cuttings, 6.1. Percentage of plants with scurfed underground stems: sprouts, 53.7; cuttings, 0.2. The results indicate that scurf infected sprouts were the most important source of scurf and that scurf free potatoes may be obtained by planting vine cuttings.

Anthracnose of Blue Lupine Is Seed-borne. DECKER, PHARES. Anthracnose (*Glomerella cingulata*) was reported from Florida in the fall of 1943 and 1946 as attacking lupine seedlings. During the spring of 1947 anthracnose was common in western Florida and southern Alabama, where it caused a material reduction of the seed crop. Stems, leaves, and seed pods were attacked and many seeds failed to develop. Seed lots from the combine contained from 4 to 10 per cent infected seeds after passing through the cleaner. Seed that bore acervuli filled with spores were taken from the warehouse in October and planted in the greenhouse. An average of 40 per cent of the infected seed produced seedling plants of which 75 per cent developed normal seedlings while 25 per cent bore cotyledons but failed to develop true leaves. Typical anthracnose lesions ap-

peared at or above the cotyledon attachment and on the leaves in 21 days. In a few days numerous acervuli filled with spores appeared in the lesions. None of the ten chemical seed-treating materials tested in the greenhouse prevented seedling infections from the seed-borne inoculum.

Breeding of Eggplants for Resistance to Phomopsis Blight. DECKER, PHARES. In 1940 two strains of eggplants, Pegan and Bengan, from India, were reported to be resistant to *Phomopsis verans* (Sacc. & Cyd.) Harter. These strains produce green to yellow fruit and bear large spines on the stems, leaves, and calyxes. No infected plants of these strains have been observed in the field, but successful inoculations have been made in the greenhouse. Crosses with the commercial varieties have produced disease-resistant hybrids without spines and with purple colored fruit. Fruit of the majority of the F_1 plants had the purple color of the commercial varieties, but a range of fruit colors, green to purple, was found in the F_2 and first backcross generations. Selections from the progenies through the F_6 and fifth backcrosses do not produce uniformly purple-colored fruit and disease resistance is largely lost by the fifth backcross. Crosses between selected hybrids appear to offer some promise in fixing a true-breeding, disease-resistant, purple fruited variety of eggplant adapted to Southern conditions.

Buckeye Rot-Resistant Tomatoes. FELIX, E. L. Fruit of the following 11 tomatoes proved highly resistant to buckeye rot, caused by *Phytophthora parasitica-terrestris*, in natural and artificial inoculations at the Tennessee Agricultural Experiment Station: Yellow Pear; Fargo Yellow Pear; U. S. Regional Vegetable Breeding Laboratory Nos. T244–0–1–4, T244–5–3, T244–10–3, T244–2–10–2, T7–013–5–52 (P.I. 79532 selection), T510–51 (P.I. 126923–51 selection), T994–51 (P.I. 126934 selection), T6–02–M6; and apparent segregates of Sherbakoff's 57 × Oxheart. Resistant fruits range from about ½ to 2 inches in maximum diameter; from round to oblong, pyriform, and papillate; from moderately thin- to very thick-skinned; and they are either red or yellow. Sherbakoff's cross (No. 57 × Oxheart) from the standpoint of fruit size and resistance to buckeye rot, as well as resistance to Fusarium wilt, appears to be the most promising for further development. Sherbakoff's 57 is a highly wilt-resistant red segregate from F_2 seed of Tucker's 9–608–9 (Earliana × currant) × Break O'Day × Bison × Bison × Break O'Day.

Preliminary Studies in the Control of Strawberry Fruit Rots by Fungicides. FELIX, E. L. Seven fungicides were applied to strawberries in 1 to 4 applications, at 5 to 7-day intervals, beginning 1 week after blossom appearance and ending 1 week before harvest began, in a series of 95 small plots, protected against drift, at Knoxville, Tennessee. They were copper carbonate 13 and 0.42 per cent, Phygon (2,3-dichloro-1,4-naphthoquinone) 4 and 0.12 per cent, Fermate (ferric dimethyldithiocarbamate) 7.5 and 0.24 per cent, and Mycoban (sodium propionate) 16 and 0.5 per cent, respectively, as dusts and sprays; Tribasic copper sulphate 14 per cent and Spergon (tetrachloro-para-benzoquinone) 7.5 per cent as dusts; and Dithane D-14 (disodium ethylene bisdithiocarbamate hexylhydrate) 0.75 per cent spray. All sprays, except Phygon wettable, contained 0.00125 per cent Triton 1956B as wetting agent. Rates of application were 40 lb. of dust and 150 gal. of spray per acre. Not any of the fungicides, as tested, appear promising for strawberry fruit rot control, except possibly copper carbonate against Botrytis gray mold, which comprised only about 12 per cent of the total rot. None seemed to affect yield, although Dithane, Phygon, copper carbonate, and Tribasic copper sulphate resulted in slight foliage injury. Dithane, even in a single early application, decidedly impaired the flavor of fresh strawberries harvested throughout the season.

Interaction of Nitrogen Fertilization and Powdery Mildew on Yield of Wheat. HEBERT, T. T., W. H. RANKIN, and G. K. MIDDLETON. Nitrogen topdressing of wheat in early spring is recommended in North Carolina. Since this practice increases the amount of powdery mildew on wheat, it became of interest to determine how this increase in mildew affects the yield increases obtained from the use of nitrogen. In two experiments nitrogen was applied at different times on plots where mildew was controlled by dusting with sulfur and on undusted plots in a split-plot design. The experiments were carried out on sandy loam soil, relatively low in nitrogen, and to which an adequate supply of phosphorus, potassium, calcium, and magesium had been added.

Since the results were similar for the two experiments, only one will be discussed in detail. A highly significant interaction was obtained between nitrogen fertilization and mildew control. Dusting had very little effect on yield where no nitrogen was applied or when 45 lb. nitrogen was applied at seeding time (Oct. 24); but when this amount of nitrogen was applied as a topdressing in the spring, the dusted plots yielded as much as 40 percent more than the undusted plots. The Feburary 1 application of nitrogen gave a significantly higher yield than the March 1 application in the undusted series, but

fell slightly below it in the dusted series. Also, the use of nitrogen at seeding time produced as high a yield as its application in March in the undusted series, but gave definitely inferior results in the dusted series. Thus the presence of mildew on wheat may affect both the optimum time for application of nitrogen and the response to nitrogen.

A Crown Rot of Alfalfa Caused by Colletotrichum trifolii. HENDERSON, R. G., and T. J. SMITH. During the summer and early fall of 1947 dying alfalfa plants were observed in a number of fields. An examination of these plants revealed a stem and root rot progressing downward from the crown. The diseased tissue was yellowish-brown to reddish-brown. It appeared that the infection entered the crown through a shoot or stubble and then involved the entire crown and tap root. Isolations from the diseased tissue consistently yielded *Colletotrichum trifolii*. Lesions were on the shoots but were not conspicious. Acervuli could usually be found, but in many instances sporulation was sparse. Although anthracnose crown rot, has not been identified in many alfalfa fields over the State, it was observed causing extensive damage at widely separated points. It is known that summer killing of alfalfa by unidentified diseases is of major importance in maintaining stands. The association of *C. trifolii* with this type of injury strongly suggests that anthracnose may be of greater importance on alfalfa than previously thought.

Relative Susceptibility of Alfalfa Varieties to Certain Foliage Diseases. HENDERSON, R. G. and T. J. SMITH. Severe defoliation of alfalfa occured in many fields in southwest Virginia in 1947. In July and August Stemphylium leaf spot (*Stemphylium botryosum* Wallroth) predominated, while in October and November Pseudopeziza leaf spot (*Pseudopeziza medicaginis* (Lib.) Sacc.) was the most important. There appeared to be a distinct difference in the amount of defoliation on different varieties. Plots of 13 varieties were examined carefully on July 3 and on October 2 and each plot scored according to the severity of the leaf diseases. A disease index on the basis of the maximum defoliation being scored 100 was then calculated for each variety on each date. On July 3, Ladak and Hardistan varieties had the greatest amount of diseased foliage and were given a disease index of 88, and 70, respectively. The Ranger variety was intermediate with a disease index of 60. The varieties with the lowest disease index were Williamsburg 23, Kansas Common 23, Buffalo 27, A–14 27, and Hardigan 31. On October 2, the scores for the several varieties followed the same trend as those obtained earlier. The varieties Ladak and Hardistan had the greatest amount of disease. Ranger was intermediate, and Williamsburg, Kansas Common, Buffalo, A–14 27, and Atlantic were the least affected. Pseudopeziza leaf spot and black stem (*Ascochyta imperfecta* Peck.) caused progressively greater defoliation on all varieties during October and November. Individual plants in certain varieties remained remarkably free of defoliation and suggested that more highly resistant strains could be selected out of the standard varieties.

Soil Fumigation for Cigar-Wrapper Tobacco in Florida. KINCAID, RANDALL R. Soil fumigation tests were conducted at the North Florida Experiment Station in 1947, using dichloropropene-dichloropropane mixture at the rate of 20 gal. per acre and ethylene dibromide (10 per cent weight) at 30 gal. per acre. Applications were made in January, nearly 3 months before transplanting. The treated tobacco crop showed the following results, as compared with an untreated crop: Substantial reduction in root knot and coarse root (nematode root rot), increases in yield ranging from 200 to 400 lb. per acre, and no important differences in grade and fire-holding capacity of the leaves.

Results from Dusting Soybeans with Copper in 1947. LEHMAN, S. G. and J. H. GRAHAM. Three varieties of soybeans, Ralsoy, Ogden, and Roanoke, were dusted six times at approximately 8-day intervals with a mixture consisting of tribasic copper sulphate equivalent to 7 per cent metallic copper, 10 per cent wheat flour, 3 per cent DDT, and 80 per cent Cherokee Clay. Control plots received the same dust devoid of copper. Only light to moderate damage from bacterial diseases occurred during the summer; as the plants reached the peak of the vegetative period, severe damage occurred on leaves from a disease not fully identified as to cause. Disease scores calculated on October 1, five weeks after the final dust application, showed 27.6 per cent of diseased leaf area on control plots. On plots receiving 30, 60, and 90 lb. copper dust per acre at each application, diseased leaf area was reduced to 19, 12, and 11 per cent, respectively. Mean yield of the three varieties on the control plots was 27.0 bushels per acre. Plots receiving 30, 60, and 90 lb. copper dust yielded 32.5, 32.5, and 32.7 bushels, respectively. A yield increase of 5.5 bushels per acre resulted from use of copper dust. Least increase required for significance at the one per cent level was 5.1 bushels.

Soybean Seed Treatment Tests in North Carolina in 1947. LEHMAN, S. G. and J. H. GRAHAM. After preliminary germination tests of treated and untreated soybean seed in steamed sand in the greenhouse, ten lots were selected for field testing. These included paired lots grown from the same parental seed in widely separated areas, McCullers and Plymouth, where weather conditions differed markedly during the ripening and harvesting period. Three aliquots of each lot were planted, one untreated, one dusted with Arasan, (tetramethyl thiuram disulfide), one with Spergon (tetrachloro parabenzoquinone). Three plantings, early, medium, and late were made. The mean increase from Arasan was 41, 80, and 8 per cent, respectively. Emergence of nine lots was increased and diseased seedlings decreased more by Arasan than by Spergon. Seed produced at McCullers gave high emergence and few diseased seedlings while seed from Plymouth gave relatively low emergence and many diseased seedlings in both field and greenhouse plantings. Emergence was negatively correlated with seed borne infection. Emergence from both untreated and treated seed was lower in the field than in the greenhouse. However, the difference from treated seed was only about one-half that from untreated seed. Field performance of seed lots can be more accurately predicted from preliminary greenhouse germination tests if treated seed are used and proper appraisal is made of seed infection.

A Special Method of Isolating Thielavia basicola from Tobacco Roots. LUCAS, G. B. The ascomycete *Thielavia basicola* is found frequently on tobacco roots infected with the black root rot fungus *Thielaviopsis basicola.* Repeated attempts to isolate the *Thielavia* resulted in failure even though numerous media and techniques were tried. However, if roots containing perithecia of *Thielavia* are washed in tap water and incubated at 37° C. on Richard's agar with filter paper as a carbon source (instead of sucrose) the fungus can be isolated from a high percentage of the roots.

The Occurrence of Texas Root Rot of Cotton in Louisiana in 1947. NEAL, D. C. *Phymatotrichum omnivorum* root rot of cotton was found in Louisiana for the first time on August 12 in Bossier Parish, the location being on Highway 10 about four miles north of Bossier City and east of Red River. Approximately 30 acres of land, embracing two separate fields, are infested at this location, and, in addition to cotton, the disease also was found attacking carrots, beans, and turnips. In a survey conducted with the Parish Agents of Caddo and Bossier Parishes from August 26 to 28, the disease also was located on August 26 near Dixie, Louisiana, in Caddo Parish about 18 miles north of Shreveport and 2 miles west of Highway 71 close to the west bank of Red River. The infested land at Dixie comprises approximately 4.5 acres, with cotton and sweet potatoes affected. Considering the acreage involved, the damage to crops at both locations is severe, the mortality in cotton being about 85 per cent and the truck crops only slightly less. All of the other Red River alluvial—neutral to alkaline soils—of the State, including the Parishes of Pointe Coupee, Avoyelles, Rapides, Grant, Natchitoches, Red River, and the southern portions of Caddo and Bossier, were found to be free of root rot, but in some of these parishes cotton rust (potash hunger) was widespread and causing high losses. With respect to root rot, it appears that the disease on the two properties in Caddo and Bossier Parishes has been present for many years and may have been mistaken for cotton rust.

The Effect of Calcium and Other Ions on the Early Development of the Radicle of Cotton Seedlings. PRESLEY, JOHN T. and O. A. LEONARD. Considerable difficulty has been experienced in growing cotton seedlings with healthy radicles for laboratory experiments. The unhealthy condition of the radicles was at first considered to be the result of bacterial breakdown, but when every precaution was taken to maintain aseptic conditions the breakdown still occurred. In an effort to determine the cause of the breakdown, experiments were performed in which the effects of moisture tension during the germination period, aeration, temperature, and the concentration and kind of ions added to the solutions were studied. Seedlings that germinated under high moisture tension were especially susceptible to breakdown. Aeration or temperature had no definite effect upon the breakdown, but elongation of the radicles was markedly affected by temperature. The concentration and kind of ions added to the solutions had a pronounced effect upon the development and health of the radicles. Calcium salts, 0.001 to 0.004 M, added to the water in which the seedlings were placed resulted in a high percentage of healthy radicles. Salts of magesium, sodium, or potassium, 0.001 to 0.004 M, added to the water, singly or in combination, appreciably hastened the breakdown of radicles. The two conditions necessary for producing cotton seedlings with healthy radicles are adequate moisture during the germination period and adequate calcium during the early stages of growth.

Bacterial Canker of Cowpeas in Oklahoma. PRESTON, DUDLEY. The most devastating disease of cowpeas in Oklahoma is bacterial canker, caused by *Xanthomonas vignicola* Burkh. This disease occurs throughout the cowpea growing area of the south. The pathogen is carried within the seed, and is spread in the field by moisture propelled by wind. Chemical seed treatments tested gave no control. Possibility of control was definitely linked with the use of resistant varieties, such as Brabham, New Era, Groit, Iron, Victor, and others. Chinese Red is the most susceptible variety under Oklahoma conditions.

Helminthosporium carbonum in Virginia. ROANE, C. W. and C. F. GENTER. *Helminthosporium carbonum* race 1 was observed on corn in Virginia for the first time in 1947. Seed of inbred K44 obtained from Indiana was planted in an isolated block with K41 to make the single cross K44 × K41. Diseased K44 plants were first observed in middle August and by September all K44 plants had been attacked and were turning brown. The ears at harvest were severely damaged. All K41 plants remained green throughout the season. In an inbred nursery 1.5 miles away, infected ears of lines C.I.5, Ky.35–7, and P–8 were found. No further evidence of the disease in the field was observed, but greenhouse tests show that seedlings of many other inbred lines may be infected with the disease.

Breeding Wheat for Resistance to Leaf and Stem Rusts in Tennessee. SHERBAKOFF, C. D. The breeding was initiated in 1937. In 1938, rust-resistant wheats—Ceres × H–44, Hope × Hussar, Kenya, Minturki, and Supreza, and 8 rust-susceptible varieties—Honor, Jones Winter Fife, Leaps, Oro × Turkey/Florence, Shepherd, and 3 local ones were crossed in all possible combinations. The F_1 seedlings were vernalized and, in 1939, the F_2 plants which looked most promising just before the time for making crosses were used to make 17 double- and 54 back-crosses to 13 soft wheats. In 1944, some of the rust-resistant segregates were backcrossed to 10 soft wheats—Yorkwin, Currell, Thorne, Trumbull, Hardired 5, and 5 local selections. The segregates were first judged by the field performance of single plants in head rows, in blocks of single-plant progenies, then in rod rows, and finally in standard yield-plot tests. The results to the present time have only begun to show practical benefits, since a number of the new wheats have just reached formal yield-test and increase stages. The greatest number of promising segregates came from crosses of Supreza × Hope-Hussar by Honor and by Head 129.

Spraying and Dusting for Control of Onion Mildew in Louisiana. TIMS, E. C. Mildew is very destructive in the State on onions grown for seed as well as those grown for bulbs. However, the disease does not develop in epidemic proportions every year. For the past four years (1944–1947 inclusive) some control tests have been conducted for onion mildew. The following spray materials were used in one or more tests: Bordeaux mixture alone and combined with DDT (dichlorodiphenyl trichloroethane), Spergon (tetra chloro benzoquinone, wettable), Fermate (ferric dimethyl dithiocarbamate 70 per cent), Puratized N5D (phenyl mecuri triethanol ammonium lactate), Tribasic copper, Lime-sulphur, Zerlate (70 per cent zinc dimethyl dithiocarbamate), Dithane D-14 (active ingredients disodium ethylene bisdithiocarbamate 25 per cent, inert 75 per cent), COCS, and Phygon (technical 23 Dichloro-1-4 naphthoquinone—98 per cent, inert 2 per cent). One copper dust was used that contained 7 per cent metallic copper and 2 per cent mineral oil in Bentonite. None of these materials gave any effective control of mildew on bulb onions, but in one test Bordeaux mixture reduced the amount of mildew in seed onions. The copper dust also showed some promise on seed onions in the 1947 tests.

A New Fusarium Wilt of Sumac. TOOLE, E. R., W. C. SNYDER, and G. H. HEPTING. A new vascular wilt of staghorn sumac (*Rhus typhina*) was discovered on the Blue Ridge Parkway, near Waynesboro, Virginia, in 1946. Numerous clumps in a 5-acre field were dead and dying, and the disease appeared to be of recent origin. Further scouting in 1947 disclosed the fact that the wilt occurred for a distance of about 10 miles along the Parkway in this area. The disease is characterized by wilting and sometimes yellowing of the foliage, followed by death of the wilted plants. The vascular tissue of roots and stems has a brown discoloration typical of Fusarium wilts. A form of *Fusarium oxysporum* was consistently isolated from affected plants. Thirteen 1-month-old seedlings were inoculated in the greenhouse. All of them wilted within 2 months, and the fungus was reisolated from the vascular tissue of all of them. Check plants remained healthy.

Effects of Inoculations with a Fusarium on Gum Flow from Naval Stores Pines. TRUE, R. P., and A. G. SNOW, JR. Isolates of *Fusarium lateritium* from pitch cankers on *Pinus caribaea* prolonged gum flow from *P. caribaea* (slash), and *P. palustris* (longleaf). The rate of flow from untreated wounds, made in commercial turpentining

operations, is reduced considerably after 5 days. With *Fusarium* inoculations made in the spring, gum flow was maintained without appreciable reduction for 3 to 4 weeks for longleaf and 6 to 8 weeks for slash. Reinoculations made at different seasons and at different distances above the first wounds have failed to maintain the original gum flow rate. Inoculations made later in the season on additional trees were partially successful only on slash pine.

Soil Treatment Control of Fusarium Wilt and Nematodes of Cotton. SMITH, A. L. Two-year studies with Dowfume W–10 (10 per cent ethylene dibromide by volume) indicate practically complete control of wilt and nematodes was obtained by applying 30 to 37 gal. of this material per acre. The acre yield of Coker 4 in 1–7 cotton was increased from 367 to 1067 lb. and of Deltapine 14 cotton from 64 to 904 lb. of lint in a test on Catawba fine sandy loam, deep phase, in 1947. This amounts to 191 per cent and 1312 per cent increase for treatment, respectively. The percentage of wilt was reduced from 52.7 to 1.8 and from 96.8 to 3.2 for the same varieties. Coker 4 in 1–7 is comparable to most available wilt-resistant commercial varieties, while Deltapine is rather susceptible. A second test on six varieties in 1947 with the Dowfume applied at the rate of 12.5 gal. per acre in the rows gave slightly less control of wilt and nematodes. A highly susceptible variety, Hurley's Rowden, was not adequately protected. Miller 610, Dixie Triumph 366, Cook 142, and Coker 4 in 1–7 with varying amounts of wilt resistance, gave yields comparable to those obtained from the heavier rates of application.

REPORT OF THE FIFTH ANNUAL MEETING OF THE POTOMAC DIVISION OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY

The meeting was held on February 11 and 12, 1948, at the U. S. Plant Industry Station, Beltsville, Maryland, with approximately 100 members and guests in attendance. Thirty research papers were presented. All of the papers in the afternoon session of February 12 were given by visiting members of the Southern Division. This was followed by a dinner and an illustrated talk on "Agricultural Potentialities in Alaska" by Dr. Olaf Aamodt.

Officers elected for 1948–49 are as follows: *President*, W. F. JEFFERS; *Vice-President*, C. L. LEFEBVRE; *Secretary-Treasurer*, J. B. DEMAREE; *Councilor*, PAUL R. MILLER.

WILLIAM W. DIEHL, *Secretary-Treasurer*

ABSTRACTS OF PAPERS

Association of Gibberella zeae and Helminthosporium sativum as Related to the Development of Wheat Headblight. ANDERSON, A. L. Conidia of *Helminthosporium sativum* germinated only 50 per cent, with short knobby germ tubes, when mixed with *Gibberella zeae*. This reaction occurred only when high concentrations of spores (at least 10^6 spores per ml. of water) were used; normal germination occurred at lower concentrations of *G. zeae*. Furthermore, *G. zeae* colonies inhibited linear growth of *H. sativum* in culture. No inhibition of seed infection by *H. sativum* on wheat heads resulted from inoculum consisting of equal mixtures of *G. zeae* and *H. sativum*; thus at 24°–25° C. an equal number of seeds became infected with each fungus after the application of mixed inoculum containing 10^5 or 10^6 spores of each pathogen. When inoculum consisted of many spores of one pathogen plus a few of the other, infections by the latter were suppressed. For instance, inoculum consisting of 10^6 spores of *H. sativum* and 10^5 spores of *G. zeae* resulted in only 8.9 per cent of the seed becoming infected with *G. zeae* as compared to 32.2 per cent with 10^5 spores of *G. zeae* alone. That *G. zeae* did not preclude *H. sativum* seed infection is due probably to the lower number of spores per unit area of host tissue as compared to the concentrations used in the germination studies.

The effect of temperature and relative humidity upon the viability of the conidia of Piricularia oryzae. ANDERSON, A. L., B. W. HENRY, and T. L. MORGAN. The conidia of *Piricularia oryzae* retained viability best under cool, dry conditions in storage experiments in which the relative humidities were controlled with sulfuric acid solutions. Approximately 75 per cent of the conidia were viable after 12 months storage at 8° C. and 20 per cent relative humidity. At higher relative humidities (45, 70, and 95 per cent) the loss in viability was rapid at all temperatures. For example, after 5 months in storage, viable conidia were present only in those samples stored at 8° C. (all relative humidities) and at 20 per cent relative humidity at the other temperatures (20°, 28°, 32° C.). The number of lesions produced per plant by conidia stored for a 5 month period varied inversely with the temperature and the relative humidity during storage, being greater on those plants inoculated with conidia stored under cool, dry conditions. These tests also indicated that the percentage germination of the conidia was not a satisfactory method for predicting spore infectivity since conidia stored at 8° C. and 95 per cent relative humidity, having then 50 per cent viable cells, were unable to cause appreciable infection.

Two Additional Mosaic Diseases of Iris. BRIERLEY, PHILIP, and FLOYD E. SMITH. The common mosaic of bearded iris is readily transmitted to *Belamcanda chinensis* by leaf-rubbing and by *Myzus persicae*, producing a well-defined systemic mottling. The efficiency of transfer makes this plant useful for indexing bearded iris. The previously described mosaic of bulbous iris, transmissible by the same means, does not infect *Belamcanda*, nor does the bean yellow mosaic from gladiolus. A more virulent mosaic from *Iris spuria* and *I. aurea*, both of the section Apogon, is transmissible to *Belamcanda* by leaf-rubbing and by *Myzus persicae*, killing this test plant consistently in about 30 days. This virus is readily superimposed on previously established non-lethal bearded

iris mosaic in *Belamcanda*, with the same fatal effect. The three iris viruses and bean yellow mosaic are transmissible to bulbous iris seedlings by leaf-rubbing or by *Myzus persicae*, inducing current-season symptoms from early inoculations, and can be reisolated in suitable test plants. Only the bearded iris mosaic has been transmitted to bearded iris, and only the bean yellow mosaic to *Vicia faba*. All except the *Iris spuria* mosaic are infectious to gladiolus seedlings. Properties of all three iris viruses have not been determined satisfactorily, but appear to be similar, as are the vector relations of these viruses.

Natural Infection of Solanum dolcamara by Phytophthora infestans. COX, CARROLL E. *Solanum dulcamara* L. naturally infected by *Phytophthora infestans* was found in Maryland on July 10, 1947. The diseased plant was growing on a fence around a garden in which tomatoes and potatoes were also affected by the late blight fungus. The pathogen was sporulating in foliage lesions on all three suscepts, but less abundantly on *S. dulcamara* than on the other two. Sporangia and sporangiophores from the three suscepts appeared identical microscopically. Inoculation of detached, healthy leaves in the laboratory showed that sporangia from each of the three suscepts were equally capable of producing infection of tomato, *S. dulcamara*, petunia, and pepper, and all failed to cause infection of *S. carolinense* L. and tobacco. The appearance of lesions and the degree of sporulation on the various leaves inoculated were the same regardless of source of inoculum. The pathogen naturally infecting these three suscepts was, therefore, believed to be the same. The possibility exists that *S. dulcamara* may function as an overwintering susceptor for *P. infestans* in Maryland.

Organic Fungicides in the Control of Certain Shade and Ornamental Tree Diseases. DAVIS, SPENCER H. Studies were conducted at The Morris Arboretum at Philadelphia, and in Delaware, using Bordeaux 8–8–100, Zerlate (zinc dimethyldithiocarbamate) 1½–100, Fermate (ferric dimethyldithiocarbamate) 1½–100, Parzate (zinc ethylene bisdithiocarbamate) 1½–100, Bioquin 1 (copper-8-quinolinolate) 1–100, and Puratized (phenyl mercuri triethanol ammonium lactate) 1 pint–100. Leaf blotch (*Guignardia aesculi*) of horsechestnut and buckeye was controlled with Bordeaux, Zerlate, and Parzate, while Fermate and Puratized gave only slight control. Zerlate, Parzate, and Puratized controlled leaf spot (*Gnomonia ovata*) of hickory; Fermate failed. Fermate controlled anthracnose (*Gleosporium fructigenum*) on sassafras. Bioquin 1 and Parzate gave excellent control of leaf blight (*Entomosporium maculatum*) of pear. Leaf blight (*Entomosporium thuemenii*) of English hawthorn was controlled by Bordeaux, while Puratized gave control only until mid-summer. No twig blight (*Sphaeropsis sp.*) was present in red oak treated with Bordeaux or Puratized. Parzate only slightly controlled anthracnose (*Gleosporium apocryptum*) of maple. Twig blight (*Myxosporium sp.*) of dogwood was not controlled by any treatment. Control of tip blight (*Sphaeropsis ellisii*) of Austrian pine was erratic with all treatments. Puratized failed to burn-out quince rust (*Gymnosporangium clavipes*) on cedar. The only injuries were: Bordeaux caused necrotic spotting of leaves and petioles on horsechestnut, English hawthorn, and red oak; Puratized caused leaf fall of sour gum (*Nyssa sylvatica*) and retarded fall coloration of sour gum and dogwood.

A Gall Disease of Blueberry Caused by a Bacterium. DEMAREE, J. B., and NATHAN R. SMITH. Galls resembling those caused by the crown gall organism (*Agrobacterium tumefaciens*) on woody plants have been reported on blueberries from Michigan, New Jersey, New York, and Oregon. Occasionally the disease becomes serious in blueberry nurseries. The galls most frequently develop on small lateral shoots near the ground. Sometimes the main stems become infested. A bacterium was isolated from galls collected in New Jersey and Oregon and has been determined provisionally as an *Agrobacterium*, probably a strain of *A. tumefaciens*, formerly called *Phytomonas tumefaciens*. This organism readily infected blueberry plants when inoculated in wounded young shoot tissues, and caused large rough galls. It caused moderate-size galls on tomato plants, and was slightly pathogenic in tobacco, ragweed, and cranberry, but failed to infect *Kalanchoe*, *Azalea*, strawberry, *Ipomoea*, and *Convolulus*. It was lethal to young aster plants.

Camellia Wilt and Root-rot. GILL, D. L. A wilt and root-rot disease of *Camellia japonica* L. has been frequently observed for the past 2 years, particularly in plants 1, 2, and 3 years from cuttings, growing in coldframes and beds. The first symptom noticed is a yellowing of the foliage followed by wilting and death of the plant. This is preceded by browning and rotting of the roots and in some cases discoloration of the base of the plants. Branches only may die when part of the root system is killed and new roots are formed. Losses range from 10 per cent to practically 100 per cent. Plants not killed show marked stunting. *Phytophthora cinnamomi* Rands has consistently been isolated from diseased plants. Inoculations resulting in infection and reisolation have been made.

This fungus has also been obtained from roots of old plants showing dying back of the branches and sudden wilting of the plant. The disease is favored by moist conditions. The varieties Pink Perfection, Prince (Eugene) Napoleon, Pope Pius IX, Hermes, and Imura are severely affected while Prof. (C. S.) Sargent and Debutante are much less affected. This disease has not been positively identified on any variety of *Camellia sasanqua* Thumb.

Yield Response of Vegetable Plants Sprayed with Dithiocarbamate Fungicides. HEUBERGER, J. W. Research data obtained over a five-year period in Delaware show that tomatoes, potatoes, cantaloupes, and cucumbers (for pickles) sprayed with zinc dithiocarbamate fungicides have produced higher yields than when sprayed with copper fungicides, even when disease control by the dithiocarbamates has been inferior. This increased yield response has been ascribed largely to the lower phytotoxicity of the dithiocarbamates. However, research on cucumbers during 1946–1947 on the effect of various fungicides on yield before the downy mildew disease appeared showed that the iron and zinc dithiocarbamate fungicides increased the yield approximately 25 per cent over that of untreated plants, that Bordeaux mixture increased the yield approximately 10 per cent, but that a fixed copper fungicide reduced the yield slightly in both years. Two theories have been advanced by others to explain the increased yield response obtained by the use of certain dithiocarbamate fungicides: (1) the stimulatory effect that is caused by the zinc that some of these fungicides contain, and (2) the utilization by the plant of the nitrogen that these fungicides contain. The writer advances the hypothesis that the carbon, and possibly the sulfur, that these fungicides contain may be the factor largely responsible for the increased yield response. This hypothesis is supported to some extent by the data presented on cucumbers.

A New Virus Disease of Blackberry. HORN, NORMAN L. A new virus disease of blackberry, *Rubus allegheniensis*, was observed in a raspberry growing district in Maryland. The symptoms consist of a strikingly variegated leaf pattern. The disease was found to be graft transmissible from blackberry to blackberry, from blackberry to black raspberry (hybrid Cumberland × Evans), and from black raspberry to blackberry. The symptom pattern is expressed similarly in both blackberry and raspberry, but there is considerable variation in the pattern expressed in leaflets of individual leaves of both plants. The variation ranges from leaflets having only a few white islands to leaflets which are nearly totally white.

Transmissibility of the Mild Streak Virus of Black Raspberry. HORN, NORMAN L. Of 45 healthy black raspberry plants grafted to mild streak infected black raspberries 34 (75 per cent) became infected. When dodder was used to test transmission, eight of 40 (20 per cent) plants became infected. Varieties used in these tests were Logan, Dundee, and a hybrid of Cumberland × Evans. Field observations indicate the possibility of several strains of the mild streak virus as evidenced by the variations in the degree of cane symptoms on the same variety. When healthy plants were grafted to field cuttings showing varying degrees of cane symptoms, the test plants which became infected showed no corresponding degree of symptom expression.

Effect of Fusarium Isolates on Two Gladiolus Varieties. MCCLELLAN, W. D. Marked differences in pathogenicity occurred when twenty mass culture isolates of *Fusarium* from gladiolus including *Fusarium oxysporum* var. *gladioli* Massey and *F. orthoceras* var. *gladioli* McCulloch were used to inoculate two varieties of gladiolus, Picardy (formerly considered resistant) and Dr. F. E. Bennett (highly susceptible). Differences were expressed both in rapidity of foliage symptom appearance and in type of corm rot. Some isolates caused a vascular rot, some a surface rot, and others caused a combination of symptoms. The pathogenicity of isolates varied from year to year. Disease severity (measured by the number of days short of the normal maturing period) of one culture was 7.0 and 106.0 in Picardy and Dr. F. E. Bennett, respectively; of another, 39.3 and 96.8; of a third, 107.5 and 107.5; and of a fourth, 107.5 and 55.4. In general, all isolates were more pathogenic in sand than in soil. The disease severity of five single-spore isolates from one culture was 9.9 and 18.3, 50.0 and 56.9, 53.8 and 46.7, 29.9 and 42.6, and 18.1 and 9.0, in Picardy and Dr. F. E. Bennett, respectively. When a mixture of three single-spore isolates was reisolated from plants of six Iridaceous genera and used to inoculate the two gladiolus varieties, marked differences in pathogenicity occurred. No morphological differences between isolates were observed.

Studies on End Rot of Stored Maryland Golden Sweet Potatoes. SMOOT, J. J. and W. F. JEFFERS. Two of the fungi most frequently isolated from end rotted Maryland Golden sweet potatoes were found to be *Diaporthe batatatis* and *Fusarium oxysporum*. Pathogenicity tests at both high and uncontrolled humidities showed approximately 80 per cent infection for *Diaporthe* and 25 per cent for *Fusarium*. In tests of temperature

relationship to pathogenicity, the percentage infection was approximately the same at 50°, 60°, 70°, and 80° F.; but amount of rot increased with increased temperatures. The disease may be produced by either organism, or the combination of both. The symptoms of the *Fusarium* end rot were shriveled, hardened ends usually occurring on smaller potatoes. The *Diaporthe* produced a collapsed, darkened dry decay that affected all sizes of roots.

Inefficacy of Ethylene Chlorobromide as a Therapeutic Agent in the Treatment of Gardenias Infected with the Root-knot Nematode. TARJAN, A. C. In an attempt to determine the efficacy of ethylene chlorobromide as a control for gardenia root-knot, 27 two-year-old cuttings of *Gardenia jasminoides*, whose roots were severely infected with the root-knot nematode, *Heterodera marioni*, were subjected to various concentrations of the chemical in a water emulsion. At time of treatment, soil moisture was 7.01 per cent and soil temperature 67° F. The plants were divided into two groups: (A) Receiving only one treatment; and (B) receiving two treatments, two weeks apart. Method of application was as follows: 4 mutually equidistant holes were punched 2 in. deep into the soil around the perimeter within each of the 8-inch pots containing the plants. Each treatment of 0.40 cc., 0.25 cc., 0.10 cc., or 0.05 cc. was divided into 4 equal aliquots, injected into the holes and covered with soil. Each group was harvested one month after its final treatment and quantitative determinations of parasite population in the roots were obtained by a modification of the Baermann technique. It was found that the plants were capable of withstanding as much as one 0.25 cc. application of ethylene chlorobromide emulsion or two 0.10 cc. applications spaced two weeks apart. The only concentration showing any degree of control of the pathogen was one application of 0.25 cc. of the emulsion.

The Meadow Nematode Disease of Boxwood. TARJAN, A. C. During recent years, a virulent disease of boxwood has caused serious decline of this plant throughout a wide area in the eastern United States. Critical examination of the root system reveals isolated lesions or entire rootlets which appear brownish-black apparently as a result of attacks by the various meadow nematodes, *Pratylenchus spp.* Badly diseased roots, however, will not always yield the pathogen which is migratory in habit and evacuates dead and almost-dead roots. Continued attack by this nematode over a number of years results in proliferous lateral root formation above the points of attack with eventual formation of a shallow, densely-interwoven root system in the upper soil layers. Above ground symptoms may include defoliation; sudden death of branches, sometimes resulting in a "stag-head" appearance; a sickly stunted growth; and various types of foliage discoloration. The latter may include varying degrees of chlorosis, sometimes appearing as thin lateral or transverse streaks, but more often involving localized areas, especially at the leaf tip, which eventually become necrotic. Foliage of lightly infected plants may present a dark greenish-bronze appearance ranging to a light yellow-orange for badly infected plants. Symptoms of the disease are usually more pronounced during periods of drought or freezing temperatures.

Abstracts of papers presented by members of the Southern Division will be in the report of that Division. Other research papers presented at this meeting were as follows:

Soil Cover Prevents Wood Decay Under Basementless Houses. JESSE D. DILLER and THOMAS W. JONES.

Effect of Incorporating Technical DDT in the Soil on the Number, Green Weight, and Dry Weight of Blakemore Strawberry Plants. M. C. GOLDSWORTHY and J. C. DUNEGAN.

Progress of the Ring Rot Organism in the Host Plant. MATHILDE BENSAÚDE GOTZ.

Variation in Phytophthora palmivora. CARL HARTLEY.

A Case of Violet Scab on Pansy Seedlings. R. A. JEHLE and ANNA E. JENKINS.

Further Observations on a Leaf Spot and Blotch of Sorghum. C. L. LEFEBVRE and HELEN S. SHERWIN.

Peppermint Wilt and Problems in Breeding for Resistance. E. C. STEVENSON.

The Effects of D-D and Dowfume W-40 Soil Treatments on Nematode Control, Yield, and Quality of Tobacco. F. A. TODD.

PHYTOPATHOLOGICAL NOTES

Preserving Culture Media.—Tubed agar medium stored on a laboratory shelf or in a refrigerator dries and shrinks within a few weeks after it is made unless some method is employed to prevent evaporation. During the last two years a simple method of preserving tubed medium in fresh condition has been used at the Potato Investigations Laboratory, Hastings, Florida.

The medium was made, tubed, and plugged and the tubes placed in clean, one-quart, glass, fruit jars. Wide-mouth fruit jars proved better than narrow-mouth ones as test tubes can be placed in them in an upright position and they hold ⅓ more tubes than the latter. Test tube plugs were pressed down carefully before tops were placed on the jars, as any cotton left between the rim and top of a jar prevents sealing. The jars of tubes were then sterilized in a pressure cooker at 15 lb. pressure for 20 minutes. Of course, an autoclave should prove equally satisfactory.

Directions for cleaning and sterilizing jars in hot water before use, proper sealing of different types of jars, and the operation of a pressure cooker are given in pamphlets on home canning of vegetables and other foods which can be obtained at any store that sells pressure cookers.

Once a jar has been opened the cover should not be replaced over any unused tubes of medium. Unused tubes of medium left in jars whose tops were replaced immediately after some tubes were removed showed contamination 3 to 4 weeks later. It appears that sufficient moisture was trapped in the closed jars to enable *Trichoderma lignorum* (Tode) Harz. and other fungi to grow through the moist cotton plugs and into the medium in the tubes. Tubed medium left in open jars remained sterile.

Potato-dextrose agar and water blanks have been preserved by the method described. Other kinds of medium probably can be preserved in the same manner. The advantages of the method are obvious for if enough jars, test tubes, and other materials are provided, sufficient medium can be made and sterilized at one time to last a year or longer and it will always be in fresh condition for immediate use.—A. H. Eddins, Potato Investigations Laboratory, Agricultural Experiment Station, University of Florida, Hastings, Florida.

Cactus Inoculating Tool.—In the course of investigations on stem rot of giant cactus[1] (*Cereus giganteus* Englm.) an inoculating tool was developed that might be useful for similar work on other succulents. This instrument, consisting of a glazier's putty gun fitted with a piece of ¼-inch copper tubing about 12 inches long (Fig. 1, A), was devised to introduce infected cactus tissue into a *C. giganteus* plant without undue injury to the plant or the operator.

[1] Lightle, Paul C., Elizabeth T. Standring, and J. G. Brown. A bacterial necrosis of the giant cactus. Phytopath. 32: 303–313. 1942.

The nozzle on the end of the putty gun was threaded with a pipe die and a coupling attached so that an automobile gasoline line compression fitting could be used on the end of the tubing. The purpose of the compression fitting was to permit easy removal of the copper tubing for cleaning.

In use, the barrel of the gun was loaded with fresh diseased cactus tissue which had been ground in a food chopper. A hole of desired depth was made in the cactus with a ¼-inch star drill, but any ¼-inch rod, brace bit, or borer could be used. The piece of copper tubing attached to the putty gun was then inserted well into the hole and the trigger of the gun

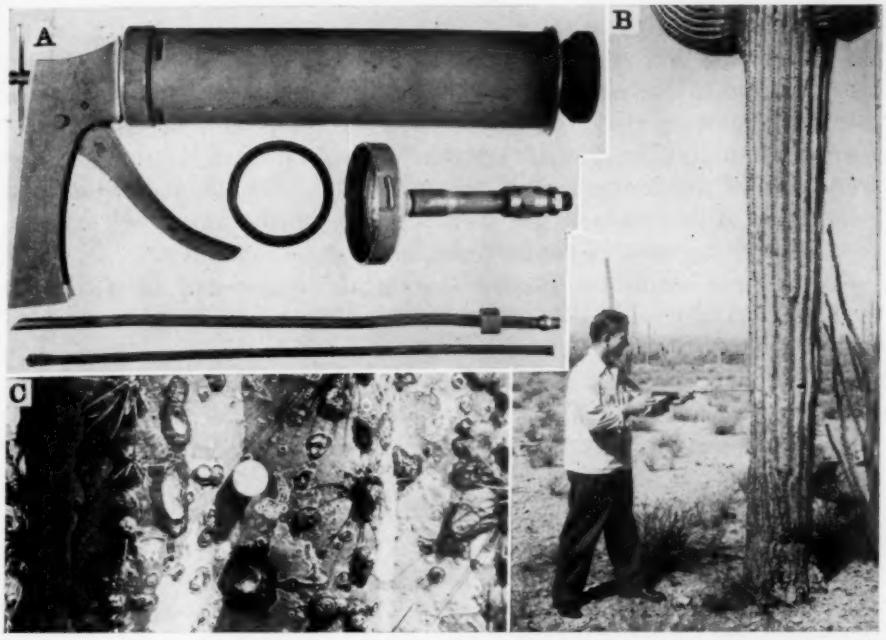

FIG. 1. A. (Top to bottom.) Putty gun, with cap detached, showing coupling on end of nozzle, leather gasket, 12-inch piece of copper tubing with compression fitting at right, and ¼-inch star drill. B. Inoculating tool in use. C. Cork plug to keep inoculum from escaping.

squeezed (Fig. 1, B). As the tubing was withdrawn from the plant the inoculum in the barrel was forced out and filled the hole. A cork was pressed into the opening to close the hole (Fig. 1, C).

The apparatus was washed out with a 1:1000 mercuric chloride solution before and after each series of inoculations. No attempt was made to completely sterilize the tool because fresh diseased tissue was used for inoculum and surface sterilization of the cactus plant with subsequent protection from contamination was considered impractical.

With this device about 20 cc. of inoculum can be quickly injected into a plant without appreciable injury to the cactus and with comparative

safety to the operator from the cactus spines.—PAUL C. LIGHTLE, Assistant Pathologist, Division of Forest Pathology, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture.

Infection of Seedling Peach Stems by Zoospores of Phytophthora cactorum.—In 1935 Dunegan[1] described a disease of peach seedlings caused by *Phytophthora cactorum* (Leb. & Cohn) Schroet. Inoculations with mycelium from pure cultures of the organism demonstrated that *P. cactorum* would invade wounds made on succulent peach stems, but plants so inoculated did not wilt. Inoculation experiments in 1947 with mycelium likewise resulted in failure to produce typical wilting.

Field studies of the disease in Arkansas nurseries, particularly during the abnormally wet spring of 1945, led to the theory that water-borne zoospores are the infective agents involved in the production of the disease in the nursery rows. The fact that *Phytophthora cactorum* produces zoospores rapidly; the development of the cankers above the soil line; the occurrence of the disease only in seasons of high rainfall; and the definite localization of outbreaks of the disease to areas in the nurseries subject to flooding may be cited in support of this theory.

By using a culture of *Phytophthora cactorum* isolated from a peach seedling in Arkansas in 1945, zoospore formation was induced by the procedure described by Drechsler.[2]

To simulate natural infection conditions, soil leachate containing motile zoospores[3] was poured into water-tight cups formed by attaching small sections of plastic tubing with cellulose tape and paraffin to the seedling stems.

In the first inoculation experiment the soil leachate containing motile zoospores was used to fill the cups around 10 seedlings. As a control, sterile-soil leachate was added to the cups of an additional 10 seedlings. Typical symptoms (i.e., watersoaked streaks) appeared in the stems of all the inoculated plants at the end of 3 days, and at the end of 5 days the typical girdling cankers appeared on these plants. Seedlings wilted and finally collapsed. No pathological symptoms developed on any of the seedlings used as controls.

Seedlings also were inoculated by transferring loops of soil leachate containing zoospores to the liquid in the cups. Each loop was examined microscopically to determine that only zoospores were used in the inoculum. Typical symptoms developed on the inoculated plants within 48

[1] Dunegan, J. C. A Phytophthora disease of peach seedlings. Phytopath. 25: 800–809. 1935.

[2] Drechsler, Charles. Repetitional diplanetism in the genus Phytophthora. Jour. Agr. Res. [U.S.] 40: 557–573. 1930.

[3] Blocks 1 sq. cm. in area were cut aseptically from a 7-day-old culture of the organism in oatmeal agar, placed in sterile Petri dishes, and flooded with sterile soil-leachate. The dishes were held at room temperature 3 to 5 days until numerous zoosporangia had developed and matured in the liquid surrounding the agar blocks. When the covers were removed from the Petri dishes the zoosporangia germinated readily, and liberated swarms of motile zoospores.

hours; the stems were girdled with cankers at the end of 5 days; and the seedlings were dead at the end of 7 days. No pathological symptoms developed on the noninoculated check plants.

Finally, to complete the chain of evidence that zoospores are capable of producing the stem-canker disease of peach seedlings, the fungus was reisolated from the experimentally diseased plants and grown in pure culture, and zoospore formation was induced. These zoospores, from pure cultures obtained from the inoculated plants, were used in a third series of inoculations and produced typical cankers followed by the wilting of infected plants.

These experiments prove that zoospores of *Phytophthora cactorum* are capable of producing typical symptoms of the stem-canker disease, and the results support the theory that zoospores are the agents that induce field infections.—JOYCE E. KEPHART and JOHN C. DUNEGAN, Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture.

Aster Yellows in Shallot and Gladiolus.—Aster yellows is one of the most common plant virus diseases, and is known to affect a large number of plants. Only recently the first monocot was added to the list, when the susceptibility of onions was reported independently by KenKnight,[1] Larson and Walker,[2] and the writers.[3] In the present note evidence of susceptibility of two additional monocots—shallot (*Allium ascalonicum* L.) and gladiolus (*Gladiolus* sp.)—is presented.

Tims[4] has reported the occurrence of a trace to as much as 5 per cent of a disease considered likely to be aster yellows in commercial shallots in Louisiana. He describes the affected bunches as bright yellow, unmottled, and having slender leaves. Such plants fail to form bulbs, so that the disease in this host is nearly self-eliminating. A number of sample bunches supplied the writers by Dr. Tims have lived for a time in greenhouse pot culture and have exhibited the symptoms he described, but have never produced bulbs or survived to a second season. The disease is not easily confused with yellow dwarf, which is characterized by distinct yellow mottling in the shallot as in the onion.

No transmission from shallot has been attempted, but aster yellows has been transmitted from chrysanthemum (*Chrysanthemum hortorum* Bailey) to shallot, the same symptoms having been noted in naturally affected plants. The chrysanthemum source plants of the varieties Mary Lennon

[1] KenKnight, Glenn. The aster yellows disease of truck crops in Idaho: Idaho Agr. Exp. Sta. Mimeo-leaflet 79. 1943.

[2] Larson, Russell, and J. C. Walker. Aster yellows a hazard in onion seed production. *In* Wis. Agr. Exp. Sta. Bul. 463, p. 50. 1944.

[3] Brierley, Philip, and Floyd F. Smith. Some virus diseases of *Alliums*. (Abstr.) Phytopath. **34**: 990. 1944.

[4] Tims, E. C. Some shallot diseases in Louisiana. U. S. Dept. Agr., Plant Dis. Rptr. **30**: 335–338. 1946. [Processed.]

Hall and Silver Ball were supplied by Lacey McColloch from a garden in Falls Church, Va. Ten six-spotted leafhoppers (*Macrosteles divisus* (Uhl.)) were fed on these source plants from December 2 to 8, 1946, moved to China aster (*Callistephus chinensis* (L.) Nees) until December 16, then fed on 10 vigorous shallot plants from December 16 to 18. The leafhoppers became established more readily on shallot than on onion. They all fed well and survived to the end of the test. Although the shallot plants

FIG. 1. Aster yellows in gladiolus (left), normal plant (right).

developed rapidly, no symptoms were detected until February 27, 1947, when one plant was noted to be somewhat more slender and upright than normal and uniformly bright yellow. None of the other plants contracted the disease. The yellow plant failed to produce a bulb and was shriveled and dead by May 9. The unaffected plants in the same pot produced normal bulbs.

Although no reisolation from the affected shallot was attempted, the close duplication of natural symptoms in this plant is considered sufficient proof that the disease was aster yellows. It is not surprising that shallot

should prove susceptible now that onions are known to be subject to the disease, as these two species are closely related. Since shallots seem to be more attractive to *Macrosteles*, aster yellows may be expected to be more troublesome on these plants than on onions.

In August, 1946, W. D. McClellan brought to our attention a single Picardy gladiolus spike that was completely virescent out of thousands of normal spikes in his plot at Beltsville, Md. All the flower parts remained green, but no proliferation was evident. The flowers eventually turned yellow and shriveled without developing the usual pink coloration. The gladioli of a seedling clone were exposed to 10 viruliferous *Macrosteles divisus* leafhoppers from chrysanthemum from December 2 to 8, 1946, when the foliage was 8 to 14 inches high. On February 14 symptoms were first detected in 1 plant. The young leaves were uniformly yellowish green, and the flower spike was spindling and green (Fig. 1). On February 24 the same symptoms appeared on a second plant. Both plants turned straw-yellow and shriveled prematurely without having shown any pink color in the flowers.

Aster yellows thus kills the tops of gladiolus rapidly after symptoms become evident. The corms developed on the two plants experimentally infected were still sound on June 20, 1947, and were beginning to produce new shoots with yellows symptoms. Aster yellows was readily transmitted to China asters from the inoculated gladiolus by means of *Macrosteles divisus*. Forty nonviruliferous nymphs were fed on an infected gladiolus flower for 2 days and then transferred to five China asters on March 8, 1947. By April 11 all the plants had developed typical symptoms of aster yellows.

The susceptibility of gladiolus to this virus is thus fully confirmed. The rarity of the disease in this crop is surprising inasmuch as the vector, *Macrosteles divisus*, is frequently found feeding on gladiolus in the field. —FLOYD F. SMITH, Bureau of Entomology and Plant Quarantine, and PHILIP BRIERLEY, Bureau of Plant Industry, Soils, and Agricultural Engineering, United States Department of Agriculture.

BOOK REVIEWS

CARTWRIGHT, K. ST. G., and W. P. K. FINDLAY. *Decay of Timber and its Prevention.* Department of Scientific and Industrial Research publication, 294 pp., illus. 1946. Published by H. M. Stationery Office, London. 12s. 6d.

This is the first modern book in English dealing exclusively and comprehensively with timber and wood decay. The authors are eminently qualified to write in this field having worked together in it for many years at the Forest Products Research Laboratory, Princes Risborough, Aylesbury, Buck, England. The subject of decay and other fungus defects of wood, and methods of controlling them, is now developed to a point where anything like a full treatment of it cannot be attempted in a single book of ordinary size. Faced with this situation, Cartwright and Findlay have shown commendable discrimination in their choice of phases to be considered and in the selection of literature that they have drawn on. Those wanting a better understanding of the factors contributing to decay and of the causal fungi and their effect on wood, and those concerned with the prevention of decay will find this a valuable text book and reference source.

The contents are taken up under 14 main headings: introduction (economic factors and historical); causes of decay; technique (isolation of fungi, cultural and staining method, etc.); physiology of wood-destroying fungi; effects of fungus decay on wood; principal decays of standing trees in Great Britain (two chapters, coniferous, and broad-leaved trees); rots of felled timber and of timber in service in the open; rots of timber in buildings and structures; prevention of decay in felled and converted timber during storage and shipment; decay of timber in buildings, mines, vehicles, aircraft, ships and boats, sleepers, poles, fencing and in horticultural use; deterioration of composite wood and manufactured wood products; natural durability of timber; preservation of wood by chemicals, and staining and discoloration of timber. There is also an appendix in which is given the British standard method of test for the toxicity of wood preservatives. This method in its general aspects is used in many laboratories outside Great Britain. Subheadings are freely used, making for rapid location of individual topics and clarity of presentation.

In the chapters dealing with the rots of standing trees, felled timber, and buildings, emphasis is placed on the causal fungi and their characteristics. Descriptions of the cultural and physiological characteristics of the more important fungi should be of special interest to many readers as information on these points has been rather difficult to find. For the same reason, many will find the chapter dealing with the physiology of wood-destroying fungi very helpful. Remedial and preventive measures are considered to some extent with reference to the individual fungi, in the felled timber and buildings, whereas general measures are considered in subsequent sections.

Although British conditions naturally receive considerable attention in places, North American readers will not find this excessive for the most part. The chapters of most marked regional character in this respect are those on the decay of standing trees. A few things might be added to the book in any subsequent revision that would further its value to American users. For example, it would seem desirable to list more of the commercial timbers falling in the durable to moderately durable groups. Brush treatment of stored logs probably would be less favored than a spray treatment in the United States and Canada, except where an end coating to control checking is needed. It is also probable that one of the anti-stain chemicals used on lumber would find more favor for log treatment than creosote. In addition to sodium pentachlorophenate for the preservation of wet pulp during storage, mention might be made of ethyl mercuric phosphate. This compound has given a good account of itself in Swedish investigations and is used commercially in this country. Other new organic fungicides are coming into use for the same purpose. "Wood Preservation," by Hunt and Garratt should be cited as it is an important modern text and reference book in English on this subject.—THEODORE C. SCHEFFER, Forest Products Laboratory, Madison, Wisconsin.

WHITEHEAD, S. TATUM, THOMAS P. MCINTOSH, and WILLIAM W. FINDLAY. *The potato in health and disease.* 400 + XV pages, 31 figs. Oliver and Boyd, London. 1945. 25s.

The first half of this book is devoted to the potato plant and its culture, and the second to potato diseases. In the first section the origin and taxonomy of the cultivated potato is discussed, and considerable space is devoted to the morphological characters by which varieties are distinguished. An appendix gives the descriptions of some 50 British varieties; their distinguishing characteristics; cultural, cooking, and keeping qualities; and their reactions to diseases, especially those caused by viruses.

Cultural methods used in the British Isles are described in detail, with references to scientific literature on various phases of potato growing. Seed certification standards and methods of particular interest to seed growers are discussed.

The section on pathology has a key to parasitic diseases and abnormalities caused by insects and non-parasitic agencies. Of the 19 parasitic diseases that are discussed in detail some, such as that due to *Armillaria mellea*, would be considered of little importance in the United States, while ring-rot (*Corynebacterium sepedonicum*) is not mentioned. The parasitic diseases are classified on the basis of pathogen taxonomy, and the characteristics and life histories of the pathogens discussed in considerable detail. A useful feature of the description of symptoms is the attention given to characteristics by which each disease may be distinguished from others with similar symptoms.

The discussion of virus diseases of the potato occupies nearly 100 pages, and covers all phases of the subject, including descriptions of the principal virus diseases, the reactions of varieties to different viruses and virus complexes, means of transmission, descriptions of aphid vectors, and practical problems encountered in control.

Judging from the simple way in which basic biological concepts, such as cell division and inheritance, are described, this book is meant to appeal to people with little background in biology. This does not mean that it is superficial or unauthoritative. It will be useful to anyone wishing a scientific reference on potato growing and disease control. Growers, and especially seed certification officials, should find it very valuable, and it would be useful to any investigator working on potato problems.—C. J. EIDE, Minnesota Agricultural Experiment Station.

CHESTER, K. STARR. *The nature and prevention of the cereal rusts as exemplified in the leaf rust of wheat.* 269 pp., 11 figures, 19 tables. Chronica Botanica Co., Waltham, Mass.; Stechert-Hafner, Inc., New York City. 1946. $5.00.

This book is an extensive review of the world literature on leaf rust of wheat and should be welcomed by students and research workers as a valuable reference to the subject, particularly at the present time when the disease is assuming increasing economic importance in the United States. Dr. Chester is to be commended for his efforts in translating the pertinent Russian literature on the subject which, due to difficulties in translating, is made available to many for the first time. The book is more than a summary of the literature. Many of the data have been analyzed and suggestions made that will be helpful in continuance of research on the subject.

There are fifteen chapters in the book with titles serving as guides to the contents. In chapter 1 is a history of the disease up to the present time. In chapters 2 and 3 are discussed the origin, distribution, economic importance, and the effect of the rust on the host plant and its yields. Here the author has presented rather conclusive data to show that in the world as a whole leaf rust is even more destructive than stem rust. Those, in North America at least, who have witnessed several of the devastating stem rust epidemics will undoubtedly be skeptical on this point. Chapter 4 deals primarily with suscepts. Information is presented on the host range of the pathogen and on the reactions of wheat varieties together with a review of results of investigations on the alternate hosts. Noteworthy is the fact that *Isopyrum fumarioides*, although present in North America as well as in other parts of the world, functions as an alternate host only in eastern Siberia. Chapters 5 and 6 deal with the symptoms of the disease on the economic and alternate hosts, and review the cytology and sexuality of the pathogen as determined primarily by the work of Allen. Plant breeders as well as pathologists will be particularly interested in Chapters 7 and 8, which deal with physiologic specialization. The author suggests eliminating three somewhat unstable differential varieties and on the basis of similarities classifies the known 129 races in 44 race groups. Both suggestions have considerable merit and if the data obtained on this basis appear adequate for the needs in our present day breeding programs, the proposed system will simplify to some extent the work of both pathologists and breeders. In Chapters 9 and 10 are considered the factors affecting the survival and development of the rust. Environmental factors such as moisture, temperature, light, physical conditions, and chemical constitution of the soil are discussed at some length. There is included also a discussion on studying, analyzing, and expressing combined environmental factors together with suggestions for correlating data of value for forecasting of epidemics at least in limited areas. The practical application will be open to question in the minds of many. Chapter 11 deals with rust dissemination, annual cycles, and epiphytotics. Dissemination of rust spores by various agents, evidence of long distance dissemination in different parts of the world, and annual cycles are adequately discussed. The last few chapters of the book are devoted to rust control by natural, regulatory, and cultural means, by the use of fungicides, and by the development of resistant varieties. The advantages and limitations of the different methods are adequately discussed. There is also a good discussion of the literature on results of breeding for leaf rust resistance. In fact, throughout the book the reader is impressed with the exhaustive search and digest of the literature that Dr. Chester has made to present a complete summary of the information on the subject.—H. A. RODENHISER, Bureau of Plant Industry Station, Beltsville, Maryland.

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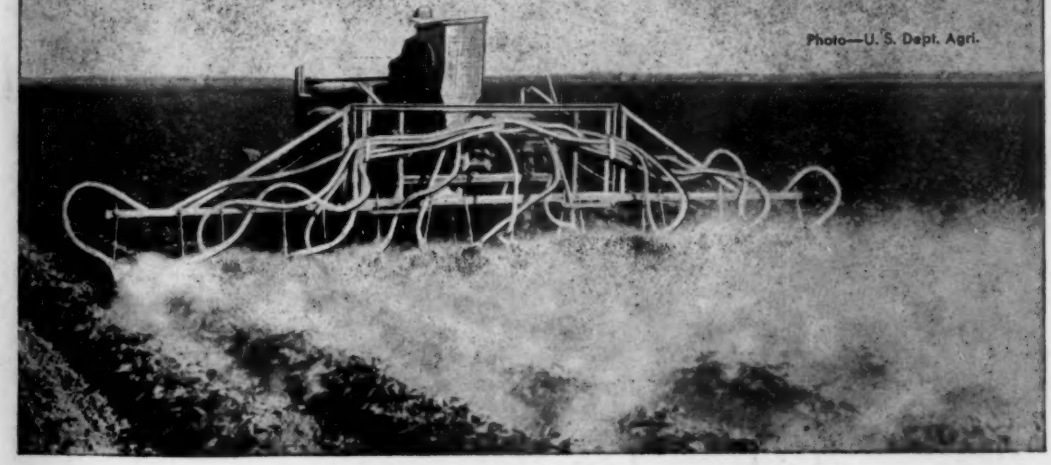

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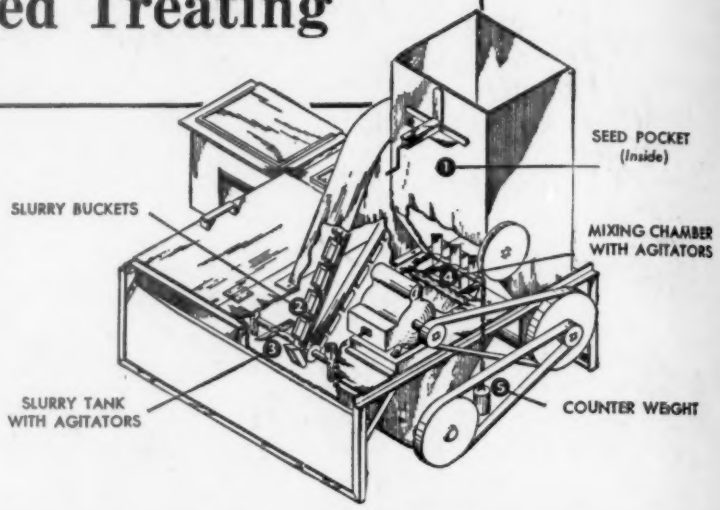

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